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# CRAFTING CULTURE AT ALALAKH: TELL ATCHANA AND THE POLITICAL ECONOMY OF METALLURGY

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*For*

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# Abstract

Tell Atchana, ancient Alalakh, was the seat of the territorial kingdom of Mukiš during the 2nd millennium BC with extensive trade ties to the wider Near East. Part of the urban fabric of this city was an active metallurgical industry characterized by several workshops located within the palace walls and the lower town. A sociotechnical systems perspective provides the background for evaluating the processes and social relations that structured the metallurgical industry and its associated technologies at Alalakh from approximately 1600-1200 BC. This work demonstrates the long-term presence of two parallel specialized metallurgical industries; one palace-based, small-scale, routinized and tapped into long-distance exchange networks, the other, vernacular, larger-scale, technically sophisticated, multi-craft, and based on the use of specific central Anatolian ore deposits and other montane resources. At an archaeological and historical level, my results de-center the Near Eastern palace economy as a driver of technological development and economic expansion and show that state power beyond the palace walls was more limited than generally considered. Methodologically, this work shows the power of multi-method archaeometallurgical studies for answering questions of broad social and historical significance when thoroughly contextualized. Finally, of key importance is a demonstration that craftspeople at Alalakh used their unique technological system to resist hierarchical organization and co-optation even as they helped contribute to its political complexity. In addition to the data presented here in the appendices, all analytical data including compositional values, contextual data, and an extensive micrograph collection has been made publicly available thanks to a Doctoral Dissertation Research Improvement Grant (DDRI) from the National Science Foundation (Grant# 1902723).

# 1 Introduction to the Research

This study is a detailed evaluation of the metallurgical industry at the archaeological site of Tell Atchana, ancient Alalakh, an urban center of the 2nd millennium BC. Taking a perspective rooted in theories surrounding the relationship of technology and society, I use an account of the local metals industry to understand the role that complex technological systems play in the development of culture. The result is a discussion that emphasizes how different ways of manipulating matter – themselves reflecting varying relationships to material things – can serve to create cohesive social units and characterize deep-seated divisions. From an archaeological perspective, this work shows that state-centered narratives of progress are rather incomplete, excluding non-state or peripheral actors and their contributions to human cultures.

The selection of Tell Atchana was based partially on its status as one of the largest, most intensively studied sites in the Near East and one of the few to have produced significant archives for the Middle and Late Bronze Age. Because of its wealth of data, it holds a crucial position in defining the history of the 2nd millennium BC in Syro-Mesopotamia and the Levant (Dassow, 2005; Lauinger, 2015, 2011; Magness-Gardiner, 1994; Niedorf, 2008; von Dassow, 2008; Wiseman, 1953; Zeeb, 2001). From the Level VII and Level IV Palace archives we have learned much about the political and social history of the region (von Dassow, 2008, pp. 73–76). Beginning with the level VII archive in the 18th/17th century BC, Alalakh was under the reign of Yarim-lim as capital of the city-state of Mukiš and vassal to Yamhad (centered at modern Aleppo) (Lauinger, 2015). Our next glimpse comes from the Level IV Palace archive, representing Alalakh during the 15th century when it was a vassal state of Mitanni (von Dassow, 2008). At the end of level IV, between roughly the 1330's and 1290's, this palace was destroyed, and the land of Mukiš brought under Hittite dominion (Yener et al., 2019b). This textual wealth meant that there was a substantial local archive against which archaeological and analytical data could be compared.

| Date BC | Aegean | Egypt | Syria-Palestine | South Mesopotamia | Tell Leilan | Tell Atchana (Yener) | Kültepe Mound and Lower Town | Kültepe N. Trench |
|---|---|---|---|---|---|---|---|---|
| *1200* | | | Late Bronze IIb | | | Period 0 | | |
| *1300* | Late Helladic III | New Kingdom | Late Bronze IIa | | | Period 1<br>Period 2 | | |
| *1400* | | | Late Bronze I | | | Period 3 | | |
| *1500* | Late Helladic II | Second | | Kassite | | Period 4<br>Period 5 | | |
| *1600* | Late Helladic I | Intermediate | | | | Period 6 | Mound 6<br>Lower Town Ia | |
| *1700* | | Period | Middle Bronze II | | | Period 7 | | |
| *1800* | Middle Helladic II | Middle Kingdom | | Old Babylonian | Leilan I | Period 8/9 (Tenative) | Mound 7<br>Lower Town Ib | |
| *1900* | Middle Helladic I | | Middle Bronze I | | | | Mound 8<br>Lower Town II | |
| *2000* | | First | Early Bronze IVc (?) | Isin-Larsa | "17 Kings who lived in tents" Leilan IId | | Mound 9/10<br>Lower Town III/IV<br>Mound 11a | |
| *2100* | Early Helladic III | Intermediate | | Ur III | | | Mound 11b | I |
| *2200* | | Period | Early Bronze IVb | | | | | II |
| *2300* | | | | Akkadian | Leilan IIc | | Mound 12 | III |
| *2400* | Early Helladic II | Old Kingdom | Early Bronze IVa | | Leilan IIb | | Mound 13 | IV |
| *2500* | | | | Early Dynastic III | Leilan IIa | | Mound 14 | V<br>VI |
| *2600* | | | Early Bronze III | Early Dynastic II/III | Leilan IIId | | | VII<br>VIII |

Figure 1-1: Chronological chart showing the new Tell Atchana periodization within the broader Near Eastern context. Originally published in Johnson et al. 2020

Much of the scholarship surrounding Alalakh is concerned with broader discussions of the history of empires, while those that concern themselves with general society examine how palace-temple economies controlled and manipulated labor. This is the result of two factors stemming from the research history of the Amuq valley in southern Turkey. The first is that the study of Alalakh as it appears in texts has become decoupled from Alalakh as an archaeological entity (Dassow, 2005). Because elites were the sole producers of texts, matters of state and economy management receive historical priority. This point gains further weight when we consider that the Amuq valley was frequently contested by rival states for both its abundant natural resources and access to lines of communication northward through the Taurus, westward to the Mediterranean, eastward to Mesopotamia, and southward to the Levant (Magness-Gardiner, 1994, pp. 38–39). Second, is the fact that the extent of archaeological investigation in the Amuq has been limited since the earliest research in the region by Sir Leonard Woolley and the Oriental Institute (Braidwood, 1937; Wiseman, 1953; Woolley, 1955).

With the resumption of excavation at Tell Atchana in 2003, a research agenda was adopted with the goals of testing and elaborating upon the previous work of Woolley, resituating Alalakh within its regional context as an archaeological entity, and the investigation of contexts outside the elite precincts of the mound. New studies of material culture have sought to examine evidence of cult and ritual at Atchana as well as more functional economic aspects of the temple precinct. Yener (2015a) details facets of cult practice in architectural features, figurines, cylinder seal motifs, and excavated sacrificial contexts showing the extreme resilience of the local cult. Adjacent to Woolley's original temple sounding, excavation has yielded iron arsenide (speiss) in proximity to the ruins of the temple area, possibly related to primary production activity (Johnson, 2020). Excavations off the summit of the mound are examining a greater variety of contexts aside from those primarily concerned with elite life. On the northeastern edge this has yielded evidence ranging from a series of domestic and possible production contexts, including multiple ceramic kilns, to a cemetery by the city wall (Boutin, 2010; Yener, 2013; Yener and Yazıcıoğlu, 2010). In Area 4, where I have excavated since 2012, excavations yielded the impressive Southern Fortress, adding substantially to our understanding of the nature of Hittite domination at Alalakh, exchange of architectural technologies in the Levant, and construction of Late Bronze Age (LBA) fortification systems (Akar, 2013).

The generation of a variety of specialist reports aimed at providing a more detailed picture of life and society in the city has been a major priority. Multiple studies have been completed looking at faunal, botanical, ceramic, vitreous, lapidary, and metallurgical evidence (Çakırlar et al., 2014; Dardeniz, 2015, 2014; Horowitz, 2015; Horowitz and Çakırlar, 2017; Kuruçayırlı, 2015; Selover, 2010). Specifically related to metals, several projects have approached the topic from more traditionalist perspectives. Selover's (2010) analysis of clothing pins from burials at Alalakh is illustrative of object-focused approaches, showing a particular interest in the social context of a specific object type and its methods of manufacture. For more general technological perspectives, an earlier publication from Moorey and Schweizer (1972) and more recent publications from Özbal (2006; 2005) highlight the traditional method of providing lists of compositional analyses for objects with limited interpretation of archaeological context.

The most recent study of metals from Tell Atchana addresses the question of Alalakh's involvement in regional exchange networks, including samples from Kinet Höyük and Tarsus, located in Cilicia, near modern Adana (Kuruçayırlı, 2015). Using lead isotope and compositional analysis on approximately 30 samples from each site, Kuruçayırlı tracked both the fluctuating importance of various ore sources for the Amuq and Cilicia – possibly from Cyprus, although not certainly – and differential alloy use across the area from the MBA to the LBII. Nevertheless, this study failed to pay significant attention to the archaeological context of sampled finds, with most of the Atchana samples coming from streets, inside walls, or in fill levels (Yener 2016, Personal Communication). While such an approach works for regional-scale analyses of metallurgical trends, it treats the archaeological site as an internally homogeneous entity. This means the loss of significant data regarding local circumstances of metallurgical practice and consumption, not to mention the chronological imprecision inherent in such a sampling method. Taking these factors into account, as a study focused on broad regional phenomena the results of this work are informative, highlighting the involvement of Atchana in regional networks through its intensive use of tin bronzes and links with distant source zones (Kuruçayırlı, 2015, p. 262).

While it has been convenient to point to the geographic position of the Amuq as evidence for its importance in the history of Syro-Mesopotamia and the Levant, the broad regional approach traditionally applied does not take full advantage of the wealth of data from Tell Atchana. To add texture to the discussion we may consider a few broad lines of evidence aside from the metallurgical. The first of these stems from the texts of Alalakh where we see, through the inclusion of Hurrian and Luwian names in what is generally considered to be an Amorite capital, evidence for a multi-ethnic population (von Dassow, 2008; Yener et al., 2019a). From this, it seems neither irresponsible nor improbable to speculate that an even larger range of diverse peoples who do not appear in the texts brought in the majority of imported goods found at Atchana. Indeed, the results here support such a claim. Examining materials of the MBA and LBA, we may speak of seals in styles attributed to central Anatolia, Palestine, and the Mitanni realm, pottery from Cyprus and Mycenae, and faience from Egypt (Collon, 2010, p. 91; Mullins, 2010, p. 54; Ritner, 2019). All these lines of evidence indicate the important place of Alalakh in the dynamic, international world of the MBA and LBA, but one might note that such evidence – generally used as tokens of status and proxies for international relations – continues to point outward. In this study I use a fundamentally different methodology for studying the metallurgy of Tell Atchana that has been alluded to in previous anthropological literature on craft specialization and organization of production (Costin, 2016, 2007, 1991; Flad and Hruby, 2007; Hruby et al., 2008) but rarely applied, particularly in the Near East. By developing and deploying a theoretically informed analytical program with the aim of providing a richly detailed account of the local political economy of metallurgy in the LBA, it will be possible to discuss and evaluate the manifestation and impact of this developing technology on society and economy.

My primary dataset is an array of analytical data collected using well-established archaeometric techniques. This includes optical and scanning electron microscopy, trace element analysis (LA-ICP-MS), and lead isotope analysis (MC-ICP-MS). The first of these allow for the identification and description of specific processes, the traces of which are frozen in slag and metal. Trace element analysis allows for the identification of different raw materials and in some instances how those materials were combined, while also providing crucial information related to the provenance of archaeological materials. Finally, lead isotope analysis (LIA or LI) allows for more specific commentary on artifact provenance. LIA and trace element analysis are ultimately complimentary. The analytical program for this research was funded through NSF DDRI Grant #1902723.

Because this project was originally conceived to test a series of hypotheses (Section 2.3), I have opted not to update my original suggestions. Aside from it striking me as disingenuous and unscientific to adjust my hypothesis section to make it appear as though I was correct from the outset, I believe it is more meaningful for the reader to see how my starting point, informed primarily by the existing archaeological literature, shifted over the course of this study. As such, the disconnect between initial hypothesis and final outcome, though unexpected, is quite intentional.

Chapter 2 introduces the principal intellectual foundations for this research, providing an extensive discussion on theories surrounding technology and society. My primary frame of reference here is the concept of the sociotechnical system, while I also draw on concepts of technological style and the organization of production. At the end of this chapter, the reader will find my primary research questions, as well as my original set of hypotheses meant to address those questions.

Chapter 3 describes the site of Tell Atchana and its history of excavation. This includes some discussion of the ancient history of the site itself, as well as its position within the regional settlement hierarchy. More importantly, this chapter includes a detailed discussion of all the contexts from which samples were drawn in this study, their phasing, and relevant top plans. Though these plans were drawn by me, they are often based on work done by Özgecan Aydın and Egemen Kaya. This discussion should help orient the reader to the general distribution of material and configuration of the site and introduces site-specific terminology that will be used throughout the study.

Chapter 4 is a discussion on relations between highland-lowland communities including a brief excursus on ethnographic examples of what may be broadly considered metallurgical communities. The inclusion of this material was deemed necessary when evidence in the assemblage under study came to show that some raw ores were being brought directly from the mountains to the site for processing. This marked a more intimate connection between the occupants of the lower town workshop and highland resource zones than had originally been anticipated. As such, this chapter raises a series of relevant points on how topography can shape social relations in general, as well as high highland and lowland populations in the eastern Mediterranean interacted from the Bronze Age into the Medieval period. The discussion of metallurgical communities, meanwhile, highlights the liminal position that these groups often maintain between highland and settled society. Overall, this chapter brings important social considerations concerning the acquisition of resources from highland areas to the fore.

Chapter 5 is primarily concerned with discussing production and consumption patterns of metals as they are currently understood. My coverage of production focuses on archaeological evidence from two examples of Near Eastern metallurgical systems that are typically held to be paradigmatic: Cyprus and the southern Levant. Because these cases are often used to argue for an intimate link between complex technology, trade, and the development of complex society, they represent a necessary backdrop for the consideration of the Tell Atchana material. In comparison with archaeological evidence of metal production from central and eastern Turkey, I question the extent to which these other examples can be truly considered paradigmatic. The second part of this chapter uses textual evidence to discuss elite management of metal production and the use of metals at Ebla, Boğazköy, and Tell Atchana, with supporting material from sites such as Mari and Ugarit.

Chapters 6, 7, and 8 contain the detailed results of archaeometric analyses. Specific methods and the questions they are meant to address are provided at the beginning of each chapter. Chapter 9 represents the combination of this data with archaeological context according to occupational period. Though spatial statistical analysis with ArcGIS was meant to be the core of this chapter, several factors lead to it being ultimately ineffective. The reasons for this failure are discussed, followed by a more traditional spatial discussion of the data and its implications for interpreting the metals industry at Tell Atchana. Chapter 10 represents the final summary of the results. Here, I return to my three structuring questions and begin to address the hypotheses I had laid out in chapter 2 directly. I address several of the more glaring disconnects between hypothesis and outcome, while also attempting to contextualize the industry of Alalakh from a technology perspective.

Together, these chapters demonstrate three important points. First, the extent to which power systems that seem similar based on texts can differ significantly in actual practice. This has a secondary effect of showing that the power of Near Eastern palace economies was more circumscribed than we typically consider. Second, the combination of multi-method archaeometric analysis with sound archaeological contextualization, though labor intensive and complex, is exceptionally powerful for illustrating the interplay between technology and society. Specifically, they demonstrate how technology can constitute a significant element of identity and how it can be used to resist political power. Third, it highlights an element of Alalakhian society that has long been recognized in texts but rarely confronted directly – its diversity. Though we cannot put a name to the people studied here, this work demonstrates the presence of a group defined by a unique class of knowledge that allows them to appear as archaeologically distinct from both their surrounding community, as well as from other archaeologically and textually known metallurgical communities.

# *2 Socio-technical Systems and their Archaeological Study*

"It is misleading to divide human actions into "art," "science," or "technology," for the artist has something of the scientist in him, and the engineer of both, and the very meaning of these terms varies with time so that analysis can easily degenerate into semantics. Nevertheless, one man may be mainly motivated by a desire to promote utility, while others may seek intellectual understanding or aesthetic experience. The study of interplay among these is not only interesting but is necessary for suggesting routes out of our present social confusion." (Smith, 1970, p. 493)

Fundamentally, technologies are socio-technical systems that are dependent on access to resources *and* require social mediation for their elaboration and development (Hecht and Thad Allen, 2001, pp. 2–3, 14; Hughes, 1993, pp. 77–78; Lemmonier, 1986, p. 164; Marx, 2010, pp. 567–568; Pfaffenberger, 1992, pp. 497–500; Pinch and Bijker, 2012, pp. 18–19). They are composed of a wide range of occupations and attendant material assemblages that function to address the needs of various social groups within the bounds established by technical traditions. To this end, social and environmental constraints will tend to circumscribe or promote particular forms of a technology, leading to discrete – materially traceable – patterns (i.e. habitus) of specialization, organization, and consumption that are not necessarily transferrable out of specific contexts (Gordon and Malone, 1994, p. 41).

While this perspective enjoys significant support, It is worth briefly highlighting a point noted by Hegmon (1998, p. 268) and exemplified in the work of Lemmonier and Lechtman, that there is often a substantial disconnect in how scholars approach the history of technology. For Lechtman, concerns about how aesthetics and ritual influenced technical practice were of paramount importance, while Lemmonier was concerned primarily with how cultural traditions structured selection of material, organization of labor, and technical approaches. To a certain degree, it is possible to characterize Lechtman's approach as being more top-down, while Lemmonier took a more bottom-up perspective. Despite a theoretical desire to overcome such a division, what this methodological dichotomy accomplishes is a retrenchment of the Marxist perspective that the ritual and aesthetic are part of a cultural superstructure, while the technical or mundane represents the infrastructure. The two are often treated side-by-side in the present work, because one of my primary goals here is ultimately to bring these two sides of the issue together.

Because essentially every stage of the metallurgical process generates some form of observable data that relates to human choice, its study is an ideal topic for approaching these issues. What I propose is a discussion that will apprehend the technical parameters of metal production through archaeometric analysis, and then interpret those results from three perspectives. First, the execution of metallurgical processes and distribution of finished artifact types will be the subject of detailed spatial analysis in order to discuss the local *chaîne opératoire* and organization of production. Also stemming from metallurgical debris, information on the types of raw material and techniques of production used within the site for metal production will allow for a general contextualization of the Alalakh metal industry in its local landscape as well as within the broader metallurgical milieu of the Late Bronze Age eastern Mediterranean. Finally, though the types of data gained from archaeological investigation can provide an exceptional level of detail, it is only through the evaluation of textual records that we can begin to approach the cultural logics of socio-technical systems. This includes principles of productive organization and economic and phenomenological views of material culture – in short, the notion of cultural representation discussed below.

In the remainder of this chapter I will present a general overview of technology and socio-technical systems. I will then follow this with a discussion of craft specialization, organization of production, and technological style as theoretical concepts useful for approaching socio-technical systems from an archaeological perspective. Finally, I will provide a general overview of how the methods outlined in the previous chapter serve these ideas and their application to the study of the assemblage at Tell Atchana. By using these theoretical perspectives in conjunction with one another and taking full advantage of the detailed archaeological and textual corpus at my disposal, it is my intention to elaborate a position that moves beyond frustratingly durable evolutionary perspectives.

Because the production of metals involves the deployment of both relatively rare resources and complex techniques in the context of variable social networks, scholars have spent significant effort in studying the role of metallurgy in the development of complex societies. For much of the history of modern archaeology and anthropology, this has taken the form of largely evolutionary approaches to the topic, where a constant linear progression is taken for granted and assumed to relate directly to relative levels of development among ancient societies (Childe, 1944; Trigger, 1986; Wailes, 1996). Within evolutionary narratives, the superiority of new materials constitutes the driving force behind this progression, meaning that those who fail to develop and exploit those techniques which have formed the steppingstones to our present moment are seen as inherently backward.

As part of this evolutionary framework, the use of metals formed the touchstone for classifying stages of cultural development as codified in the three-age system of stone, bronze, and iron. The narrative begins in the later Neolithic with the working of colorful secondary oxide ores and native metals to produce simple trinkets and basic tools such as awls. Working techniques are extremely simple, being largely limited to cold working and grinding. Archaeologists such as Childe (Trigger, 1984, p. 3) referred to those living at this stage as barbarians, associated with minimal social hierarchy and governing institutions. The next stage, generally attributed to the Chalcolithic, is characterized by the development of crude pyrotechnologies for smelting oxide ores and the discovery of annealing techniques. There is still an emphasis on the production of jewelry and related items, but the corpus tends to expand to include some tools and basic weapons. Here, we might see the development of a rudimentary social hierarchy, but translation of power into material benefits within this hierarchy is limited.

As societies become increasingly complex, smelting processes expand in scale and gain the capacity to smelt sulfide ores, generating larger quantities of purer metal to manufacture an ever-expanding range of objects. Along the way, techniques for smelting metals aside from copper appear, allowing the manufacture of alloys. From an evolutionary perspective, the driving force behind this progression is state institutions, with the territorial state near the pinnacle of development. Here, the development of tin-bronze is considered a high-water mark, becoming the dominant metal by the Late Bronze Age and maintaining prominence into the Iron Age. The apex of ancient metallurgy is then the development of iron smelting. The primary significance of this stage is the perception of iron as the “democratizing metal,” whose abundance allowed people to use metals for the mass production of everyday implements and weapons (Muhly et al., 1985, pp. 67–68).

The narrative here is a unidirectional story of progress towards greater productive efficiency and the invention of increasingly advanced materials, fitting neatly with modern perceptions of scientific progress and development (Hecht and Thad Allen, 2001, pp. 5–7; Pinch and Bijker, 2012, pp. 16, 19; Adams, 1996, pp. 3–5).[1] The purpose this narrative has tended to

[1] Regarding Pinch and Bijker’s (2012) commentary on p. 19, a further aspect of this narrative is the notion that “science discovers, technology applies.” For those interested in exploring this

serve, beyond giving meaning to earlier purely descriptive accounts of material culture, has been to characterize technologies as crucial in catalyzing the development of complex societies. This appears most clearly in the work of V. Gordon Childe, as well as Karl Marx (Childe, 1944, 1930; Trigger, 1986, 1984; Wailes, 1996). For Childe – and other evolutionists – the development of metal technologies necessitated the creation of increasingly complex systems of organization to acquire resources, generation of food surpluses to support craft specialists, and the establishment of ever more elaborate means of controlling both systems. The end goal, of course, was the development of the industrialized, bureaucratic nation-state. As Adams (2001, pp. 345, 350–351) has emphasized, the accumulative and unidirectional nature of these narratives ignores the fact that complex systems do not develop linearly and that such systems are dependent on the maintenance or improvement of local equilibrium conditions for their survival. This has been most effectively illustrated in the expansion, contraction, and change of large-scale food producing societies of the ancient world in response to population growth, climate change, and social instability (Adams, 2001, pp. 353–356), but the applicability of this concept to any other technological system is readily apparent.

Looking back from our present moment does give such unilinear evolutionary narratives a veneer of truth, largely because we are the living result of specific sets of historical processes whose paths seem the only reasonable option. Nevertheless, the vast majority of decisions that form aggregated human history were taken with a relatively short-term perspective in mind, and so it is impossible to understand processes of cultural development without specific context. Thus, archaeologists have come to understand that technologies are involved in the elaboration

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concept further, it is worth looking at (Smith, 2011) and (Rehren and Martinón-Torres, 2008) as illustrative examples of its fallacious nature.

of various cultural sub-systems that form part of a much larger whole, and their specific manifestation is dependent on cultural context (Boscher, 2016, pp. 26–29; Lehner, 2015, pp. 20–21; Thornton and Roberts, 2014, p. 2). As a few general examples, we may refer to counterintuitive patterns of copper use, shifting from utilitarian to ornamental during the latter portion of the Old Copper Complex (1500 B.C.) along the Great Lakes (Pleger, 2000, p. 171), or the neglect of gold, lead, and tin resources in Central Africa until the appearance of Muslim traders made their exploitation socially acceptable and beneficial (Killick, 2009). Alternatively, Gordon and Killick's (1993) study of Adirondack bloomery furnace operation contrasted with east African methods has illustrated the complex ways in which market forces, natural resource availability, and cultural context shape the form and practice of technological systems. Finally, in areas such as Mesopotamia, where the raw materials necessary for metal production are completely lacking, we see the development of an intricate metallurgical industry supplied by an elaborate system of trade networks, all based on a highly regulated, and at times coercive, system of personnel management (Moorey, 1994, pp. 258–268; Zaccagnini, 1983; Sasson, 1968).[2]

## 2.1 Technology, Society, and Archaeology

The concept of technology is a relatively recent addition to the global lexicon, appearing as a discrete term during the 17$^{th}$ century in reference to the study of the mechanical or "useful" arts (Marx, 2010, p. 562, 1984, pp. 641–642; Smith, 1967). As Marx has noted (2010, pp. 562–563), the modern vernacular meaning referring to advanced techniques or the objects resulting therefrom,[3] usually conceived of as 'applied science,' is a substantial departure from the earlier

[2] The article by Zaccagnini (1983) is relevant to this point in its entirety, but pages 256-259 are worthy of particular note in as far as they emphasize the special value of skilled craftspeople.
[3] This is, for example, the definition implicit in Gordon and Malone (1994, p. 11).

definition, while also being significantly narrower in scope. Sigaut (1993, pp. 422, 424) has generally sought to retain ‘technology’ as a science of technics, with technics defined as goal-oriented material action. Similarly, in Dobres and Hoffman (1994, p. 212) technology is production-related social action, the core difference being that they view materials and technologies as inherently mediated by social systems. More recently, Pias (2011, pp. 180–181) has stated that technology is “a relay between technical artifact, aesthetic standards, cultural practices, and knowledge. Technology does something, not is something.” Notably, all three of these perspectives are reconcilable with one another, since the primary difference is their degrees of specificity. I would suggest that the vernacular perception is what most scholars mean when they utilize the term generally, while those taking technology as a specific subject follow the meaning of Sigaut, Dobres and Hoffman, and Pias, which I will expand upon below.

#### *2.1.1 Technological Determinism and Technological Somnambulism*

The general prevalence of the vernacular usage of technology has resulted in some serious misunderstandings over time. As Pfaffenberger (1992, pp. 491–492, 1988, pp. 236–237) has noted, in archaeological and anthropological circles, technology has often been viewed as analogous to material culture, which is then somehow viewed as external to culture itself while also situating the knowledge behind technologies outside of the cultural equation. From this starting point two perspectives arose: technological determinism and technological somnambulism (or possibilism) (Ingold, 1997, p. 107; Pfaffenberger, 1988, pp. 236, 238). From the deterministic point of view, technology is a form of applied science, and therefore a largely autonomous manifestation of natural law, the deployment of which demands specific forms of social organization (Pfaffenberger, 1988, p. 239). By contrast, technological somnambulism suggests that technology consists merely of ‘making’ and ‘doing,’ with the implicit suggestion that modes of production have little bearing on, and are unaffected by, cultural concerns, while the objects produced merely establish possibilities for human action. To utilize an exaggerated example, the implication here is that we could take a Mesolithic cave dweller, hand him or her an assault rifle, and the impact on their practice of hunting or warfare would be minimal. The result of these perspectives, as Pfaffenberger (1992, pp. 491–492) has lamented, was a progressive abandonment of material culture and technology studies as intellectually sterile because the relationship of technology to culture was thought too obvious or largely irrelevant.

Following from these two broad categories, we can then suggest that archaeologists have tended to utilize the concept of technology in three general ways. The deterministic perspective has traditionally been deployed by proponents of evolutionary models of social development, the most frequently cited example being Childe's discussion of metallurgy in the development of complex society (Trigger, 1986, pp. 4–5; Wailes, 1996, pp. 4–5). Alternatively, we may look to White's (White, 1949, p. 14) rather more direct statement regarding Eli Whitney and the cotton gin that "had Whitney died in the cradle the evolutionary process expressed in technology would have produced a machine for ginning cotton." This being said, it would be unfair to label all proponents of evolutionary perspectives as uncritical technological determinists, with some practitioners using optimized models as a heuristic device (Kuhn, 2004, p. 563). Arguably we could also include some elements of processualist thought under this line of thinking in as far as Binford's (1962, p. 219) classes of techno-artifacts map onto particularly defined types of cultural systems, though their articulation is more clearly expressed through the use of middle-range theory than that seen in evolutionary narratives. However, in constructing technology as an area for study, I suggest that Binford is falling into the trap of over classification (Sigaut, 1993, p. 422), rendering most explanations overly mechanistic.

Technological somnambulist perspectives show greater variation in their assessment of technology, but most have two features in common. First, they construct narratives of social change from a top-down perspective, often with a focus on elites as a prime mover. Second, and in line with their elite focus, they operate from a generalizing point of view. A quintessential example of this is the ‘political model’ of specialization outlined by Brumfiel and Earle (1987, p. 3), emphasizing top-down impositions of technologies and organizational systems in service of state power (see also; Baines and Yoffee, 1998b). This suggests that craft specialization and their associated technologies are created and promoted by social elites, which amounts to a claim that technologies and their practitioners are simply pawns that can be monopolized and used to create and entrench systems of political power. What is especially worrying about this is the implication that political power was somehow inescapable and that non-elites had only minimal agency to resist it. More clearly somnambulist perspectives manifest in many early (and some current) archaeometric accounts, especially those concerned with the development of metallurgy. In these cases, emphasis rested on identifying the natural scientific potential of ancient societies with the implicit assumption that the development of more advanced material sciences was a distinct motivator in its own right. This meant that cultural context was often cast aside as mere window dressing. Here, technical advances considered significant in reference to modern technological concerns (i.e. efficiency, scale of production, maximization of production per unit labor) formed the basis for evaluation of ancient technologies, resulting in classifications of “advanced” or “primitive” methods with limited regard for how well they performed their cultural role (Ingold, 1997, p. 107). This is commonly seen in reference to hunter-gatherers (Ingold, 2000, pp. 27–39), but can also be seen in judgements of African and Indian iron making (Elwin, 1942; Killick, 2015).

### 2.1.2 *Science, Technology, and Society and SCOT*

During the 1970's a divergent understanding of technology and approaches to its study emerged as a result of research being conducted by formally trained material scientists and historians with a particular interest in interactions between technology and society. A major contribution of this research, falling under the rubric of Science, Technology, and Society (STS) studies, was the socio-technical system, stemming from the study of large-scale technologies such as railroads and electrical grids (Hecht and Thad Allen, 2001, p. 2; Hughes, 1993, pp. ix–x; Marx, 2010, pp. 567–569; Pfaffenberger, 1992, p. 493). This was a fundamental shift from identifying technologies by their most obvious synecdoches, such as the steam locomotive for railroads or power plants for the electric grid; instead envisioning them as complex systems that constitute "total social facts," encompassing both material and behavior as a complex system (Marx, 2010, p. 567; Pfaffenberger, 1988, p. 249). As a result, STS scholars recognized that the social milieu of these material assemblages exerted a significant influence on their form, meaning that they were not solely the product of the engineers who built them, despite all representations to the contrary.

If the sense of technology elaborated by enlightenment thinkers characterized machines as a means toward an idealized social end combined with an understanding that it was human uses of such machines that were socially significant, the perception engendered by the advent of international-scale technological systems in the 19$^{th}$ century showed just how much people had given themselves over to the idea of technology as an independent engine of social development and progress (Marx, 2010, pp. 564–565, 1984, pp. 641–645). What scholars working in STS sought to accomplish was the demystification of technologies as autonomous entities in order to investigate the systems and people behind them as drivers of social phenomena.

> "Our data are in the nature of artifacts, whether these be pots or roads, sculpture or irrigation canals. The one element common to all of these material things, however, is that they are all products of technological processes. Each is the result of some human technology, each involved work of some kind or play of some kind. Since certain aspects of any technology remain an inextricable part of its products, appropriate study of artefactual materials starts us on our way to a fuller understanding of earlier technologies and, thereby, of the societies that utilized them. Even if there is little else that we can reconstruct about a culture from examination of any one of its artifacts, we *can* say something about the technology that produced that artifact—often a great deal." (Lechtman and Steinberg, 1979, p. 140)

According to Lechtman and Steinberg, the creation of any one artifact was the sum of a wide range of social relations not illustrated in the textual record and not entirely contained within the morphological features of the artifacts themselves (Gordon and Malone, 1994, pp. 16, 21). The production of copper artifacts, for example, requires bringing together experience in mining, charcoal making, smelting, logistics, casting, and smithing. Each one of these activities have specific operational parameters determined by natural law, but their specific manifestations and associations in a given society depend largely on cultural considerations that extend across the entirety of a social system (Adams, 2000, p. 103).[4]

A series of recent studies has illustrated this beautifully for early Near Eastern metallurgy, emphasizing the impact of unique circumstances prevailing in highland and lowland communities on the development of early metallurgical industries (Lehner and Yener, 2014; Thornton and Roberts, 2014). One of the major findings of Yener's (2000, p. 10) work on this topic was that, contrary to previous hypotheses regarding supposedly marginal highland metallurgical industries, these regions were often loci of technological invention and innovation without the need for massive outside investment as predicted by evolutionary and core-periphery models (Wailes, 1996). Even by the fifth millennium BC, we see the development of precocious

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[4] As an example, see; (Oppenheim, 1970, pp. 6–7)

production processes including the use of complex two-piece molds, sulfide ore smelting, and the development of administrative technologies for the management of productive activities, suggesting a motivating factor other than outside demand. During the third millennium BC, we then see the establishment of independent metallurgical communities in the Taurus Mountains, which were clearly not subservient to the lowland centers with which they often traded, as has been suggested in the past. Crucially, this research has forced a reconsideration of the role of smaller highland settlements and a reevaluation of processes of technological and economic development.

While the preceding example is related to primary production practices, there is also the question of secondary production, which is often more strongly influenced by broader cultural concerns as varied as environmental adaptation to styles of combat (Bunimovitz and Lederman, 2012, pp. 103–104; Killick, 2004; Lechtman, 1993, pp. 245–247, 1984, pp. 3–4; Smith, 1970). This was the fundamental premise of Lechtman's (1993, 1984) work on Andean metallurgy, which was concerned not merely with outward appearance, but also with the intrinsic qualities of artifacts as a means of generating an ideological advantage, leading to the use of complex surface enrichment techniques. Another example of concern with the intrinsic qualities of man-made materials is the peculiar case of the 2$^{nd}$ millennium BC glass texts from the library of Assurbanipal (668-627 BC) at Nineveh, originally published by Oppenheim (1970). In this series of texts, Mesopotamian scholars presented technical descriptions of how to produce several types of glass, complete with a brief set of preparatory rituals, descriptions of the furnaces to be used, and the types of glass to be produced. What is particularly interesting here is that many of the glasses are referred to using names for stones, showing a conceptual overlap between natural and human-made materials despite a clear understanding of the technical processes involved.[5] Beyond this, however, Shortland (2008) has emphasized that these texts extend beyond technical characterizations of a chemical process, spilling over into medical and religious practice and highlighting the blurred boundaries between science, religion, medicine, and magic (Eleanor Robson, 2001, p. 54 in; A. J. Shortland, 2008). Of course, considering these relationships is something that anthropologists, archaeologists, and the ancient elites we have traditionally focused on, have generally avoided.[6] That these Mesopotamian texts represent a unique occurrence should serve to emphasize this point - as Sigaut (1993, p. 420) described it:

> "…it is not only anthropologists who feel ill at ease with technics. The same has been true of intellectual milieu since the appearance of writing, and true perhaps of all societies whose hierarchical structure was sufficiently developed to include an elite exempt from at least some manual tasks."

In order to investigate technology from the STS perspective, Lemmonier (1986, p. 152) suggests that we must consider at least four things: material, tool, action, and specific knowledge.

> "Techniques form a system, and they do so in three ways. First of all each technique, arbitrarily defined, is the locus of multiple interactions and of constant adjustments among its elements: without the action animating it and without knowledge of its effects, the tool is nothing. Action itself is constantly adapted to transformations in the material, to the characteristics of the tool, to the evolution of know-how; technical knowledge in turn takes account of the available tool, of the effective action, of the material worked, and so forth. But in a given society the diverse techniques likewise unceasingly refer to one another. They can, in fact, share the same resources, the same knowledge, the same sites, the same actors. Moreover the use by some techniques of the products of others, as well as

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[5] The terms *kūru* and *šadū* indicate "genuine" and "artificial," respectively. Thus, lapis lazuli (Akk: *uqnû*; sum: na₄.za.gìn) could be designated literally as *uqnû kūru* (lapis of the mountain) or *uqnû šadū* (lapis of the kiln). Other instances – all in Akkadian – where we see this usage include *ḫulālu* (possibly a banded agate), *ṣurru* (obsidian), *pappardillu* (unknown), and *mušgarru* (unknown) (Oppenheim, 1970, pp. 9–11).

[6] Knapp (2000) has discussed this issue at length with more direct reference to the ancient Mediterranean, emphasizing more the tension between practitioners of so-called 'science-based archaeology' and run-of-the-mill archaeologists. Also see; (Adams, 2000, pp. 97–99).

> the existence of operational sequence or of technical principle in common creates among the multiple relations of interdependence, which confer on them a systemic character. Finally, we shall see that the cultural representations of techniques by a given group, and notably their classification, add yet more to their systemic character.” (Lemmonier, 1986, p. 154)

The first portion of this quote concerns personal skill or experience, presented in schematic fashion (cf. Ingold, 1997, p. 111; Kuijpers, 2018, 2012). These parameters come from long practice in a profession and are signaled by any number of factors. In the case of smelting techniques, it may be illustrated by slags containing a minimum of absorbed metal, showing mastery over the management of furnace operation and manipulation of charge composition (Bachmann, 1982a). In a finished object, the criteria tend to be more subjective, but properties such as evenness of shape, thoroughness of annealing, or the deployment of complex operations such as surface coating can suggest proficiency in increasingly difficult working methods, as well as a deeper understanding of the nature of metals as a material. The deployment of these working techniques in the service of definite goals then takes us back to the more abstract cultural rules of manufacture alluded to above.

The second half of Lemmonier’s statement refers to cooperative technologies. These activities share strongly overlapping material and technical requirements, though the cultural contexts where their products are deployed may vary significantly (i.e. Oppenheim, 1970, pp. 6–7). Examples of this include metallurgy and glass production or, in certain highly specialized contexts, various types of smithing. In all cases these disciplines require a thorough understanding of pyrotechnology and rely on similar sets of raw materials and techniques, albeit with different outcomes and social implications (Rehren et al., 1998, pp. 242–247; Shortland, 2008). Because of this technical synergy, such technologies are often found in similar if not the same locales or have similar archaeological footprints.

As a final observation on Lemmonier, the last sentence of the quoted passage deserves comment. In the two preceding paragraphs, Lemmonier's factors manifest themselves both in finished objects and in associations between loci of production. Concurrently, the former applies largely to individual knowledge, expertise, skill, and choice while the latter refers to shared knowledge and understanding (tradition) between groups of artisans. The "cultural representation of techniques" is the point of articulation between the technical understanding of the artisan and the more generalized pool of knowledge and classificatory systems in a society. The Mesopotamian glass texts mentioned above represent a salient example of this articulation in as far as they list the criteria used to judge and execute productive processes, while also providing the accompanying layman's classifications of finished products and, crucially, identifying the craftsman as one who is capable of acts of natural creation. As Lemmonier notes, this shows a distinctive set of vocabulary and practices that highlights the independent, codified nature of production while also showing its articulation with the broader culture and its own organized systems of classification. While the technical system can be apprehended through investigation of finished objects and production debris, the only way to gain a glimpse of broader cultural systems in the archaeological setting is through textual sources (see also; Ingold, 1997b, p. 127).

A seminal example of this is Helms' (1993) work on the ideology of craft in the expression of cultural ideals. Through text and ethnography, Helms links the exercise of craft production to royal ideology and the characterization of community leaders as being able to provide for the needs of their subjects, master qualities of heavenly personages, and communicate with the realm of the divine. In the case of Mesopotamia, this was specifically linked to the king's ability to tap into the intelligence and cleverness of deities such as Enki, demonstrating a capacity to exert influence over the far reaches of the world through the acquisition of rare resources – including people – and to exhibit qualities of mastery (Moorey, 1994, pp. 272–273, 276).

Since the emergence of STS, the ideas generated therein have had a significant impact on social constructivist perspectives in archaeology. From this standpoint, technology refers to productive processes shaped by broad cultural considerations and characterized by patterns of variation and selection (Dobres and Hoffman, 1994, p. 212; Ingold, 1997, pp. 110–111; Lechtman, 1993, p. 244; Lechtman and Steinberg, 1979; Lemmonier, 1986, pp. 151–152; Martinón-Torres and Killick, 2013, pp. 6–7; Pfaffenberger, 1992; Pinch and Bijker, 2012, pp. 21–23; Sigaut, 1993, p. 424; Smith, 1970, 1967). As such, technologies are composed of a series of culturally specific traits meant to achieve clearly defined outputs from technical processes based on requirements of aesthetics, organization of labor, ritual, technical approaches, and selection of material (Costin, 2016, p. 2; Killick, 2004, p. 571; Lechtman, 1993, pp. 269–274; Lechtman and Steinberg, 1979, pp. 153–154; Lemmonier, 1986, pp. 154–156). However, because societies are rarely culturally homogeneous, any of these requirements is subject to re-definitions by "relevant social groups" such as producers and consumers (Pinch and Bijker, 2012, pp. 23, 28). Here the concept of 'performance characteristics' formulated by behavioral archaeologists (Schiffer, 2011, pp. 26–28) is important, as it suggests that choices made in technical processes are directly reflective of compromise between producer and consumer priorities (Gordon and Killick, 1993; Killick, 2015). This means that shifting priorities on the part of relevant social groups are given material expression in final products and production debris, which can then be apprehended archaeological and archaeometrically through the study of the *chaîne opératoire* (Kuijpers, 2018a; Martinón-Torres, 2002, pp. 35–36).

Following the STS rubric, many archaeological scientists have expended significant effort investigating aspects of the *chaîne opératoire* in the manufacture of specific objects and types of material (Boscher, 2016; Charles, 1967; Pleiner, 1979; Smith, 1985). What tended to be lacking, however, was a capacity to contextualize these activities archaeologically and to situate their manufacture as part of a far-reaching cycle extending from the point of raw material extraction to the abandonment of objects and their deposition in the archaeological record. In other words, what is the archaeological context of the *chaîne opératoire,* how is it involved with other *chaînes opératoires* in the local assemblage, and how does it relate to the broader site. Veldhuijzen's recent work on pre-Roman iron production in the Jordan Valley shows the immense value of situating productive processes archaeologically, and from this account it is readily apparent what could be gained by approaching productive micro-contexts from a multi-scalar perspective (Frisch, 1985; Veldhuijzen, 2009; Veldhuijzen and Rehren, 2006; Veldhuijzen and van der Steen, 1999). This work illustrated beautifully the amount of detail that may be acquired archaeologically, however, it only represents one level of concern in the technical system (Adams, 2000, p. 113; Gordon and Malone, 1994, pp. 11–14).

In closing his article on the topic of accelerated technological change, Adams (2000, pp. 113–115) makes a point of stressing the complementarity of archaeological and historical approaches to the study of ancient societies. A significant portion of this complementarity is the realization that the sources deployed within either tradition are inherently biased towards the perspectives of the people who created the datasets that we investigate. As such, any attempt to avoid simply repeating and recreating those biases must take account of both bodies of data. In this case, it is important to recognize that beyond the biases reflected in historical vs. archaeological archives, there are also inherent biases present in different scales of archaeological data. I suggest that a tendency to try to locate drivers of social development at bounded scales of analysis is partially responsible for the myopic views of technology inherent in determinist and somnambulist perspectives discussed above.

## 2.2 Technological Style and Craft Specialization

It follows, then, that one fruitful avenue of research into the systemic nature of technologies is a flexible, multi-scalar approach that investigates the variable sets of tools, know-how, and materials deployed at differing scales of analysis (Dobres and Hoffman, 1994, pp. 212–214; Lechtman and Steinberg, 1979, pp. 141–144).

One result of attempts to enact precisely this agenda at a micro-scale has been the concept of 'technological style.' According to this view, technologies are characterized by an interplay between culturally specific habits and tastes, which determine the goals of a given technology, and individual traits accruing from processes of educating new artisans – most often referred to as *techniques du corps* (Gordon and Malone, 1994, p. 14; Sigaut, 1993, pp. 421, 424).[7] Put differently, artisans may use a variety of technical solutions to satisfy culture-wide aesthetic preferences or behavioral practices (ways of eating, drinking, cooking, etc.…). When we see a consistent set of technical solutions deployed to address such criteria, then we can refer to a technological style.[8] However, multiple technological styles may be observed within a single culture, often referring to individual "schools" of practice. Dietler and Herbich (1998, p. 234)

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[7] See; (Dietler and Herbich, 1998, p. 236) for a discussion of two conflated meanings of technological style. Here I use the term as developed in STS, referring to patterns seen in material as a result of technical processes. *Techniques du corps*, which serves as the basis for an alternative understanding, refers to ways of doing. While the two are certainly linked in many cases, they refer to distinct topics.

[8] The development of skeuomorphs for metal vessels is a good partial example involving the use of particular aspects of pottery making techniques to achieve a specific outcome in appearance and drinking style.

summarized these concerns in the form of two questions: "how does material culture originate in its social context?" and "what social and technical roles does material culture serve and in what ways does material culture, in the performance of these roles, reciprocally affect social structures and processes?"

One arena where this is apparent are early traditions of arsenical bronze production in Iran versus Anatolia. In the former, by the Early Bronze Age (EBA) an apparent tradition of direct, intentional production of arsenical copper developed, while in the latter a less controllable process involving the smelting of polymetallic ores predominated, albeit accompanied by a range of noteworthy intentional products such as the Horoztepe bull (Boscher, 2016, p. 31; Rehren et al., 2012; Smith, 1985; Thornton et al., 2009, p. 314).[9] The use of arsenical bronzes shows significant variation. Earlier stages are associated with the production of decorative items with striking surface effects, while in later periods their deployment is primarily utilitarian, showing particular longevity in central Iran (Boscher, 2016, p. 30; Charles, 1967; Helwing, 2009, pp. 213–214; Mödlinger and Sabatini, 2017, 2016, pp. 71–73; Rehren et al., 2012, p. 1717; Smith, 1985). It could be suggested that, because societies on the Iranian Plateau had access to the necessary materials to intentionally produce arsenical bronze of consistent composition, they were in a better position to use this material for utilitarian objects requiring predictable mechanical characteristics. This, in turn, would have made the adoption of more expensive tin bronzes less ideal from an economic perspective, delaying their adoption until either tin became

[9] There remains significant scholarly debate on the question of intentionality for the production of arsenical copper via the smelting of polymetallic ores. Boscher (2016, pp. 29–31) has provided a summary and theoretical treatment of this topic in his study of Early Bronze Age arsenical copper production. From my own perspective, while the production of this metal from polymetallic ores may be considered unintentional in as far as little control could be exerted over the final composition, the exploitation of such ores with the intent of producing a specific type of metal seems beyond question.

common enough to make its use economical, or social tastes (i.e. aesthetics) shifted to preferring the characteristics (i.e. gold coloration) of tin bronzes.

If technological style refers to the repeated occurrence of individually specific traits in service of culturally specific goals, craft specialization is one type of context within which those individual traits develop, while organization of production describes their mobilization to address cultural needs. Neither is wholly independent of the other, but it is heuristically useful to mention them separately in as far as the former is more relevant to the actions of individuals, while the other is more systemic in character. Following Costin (2001, p. 275, 1991, pp. 3–4), specialization may be characterized as "a differentiated, regularized, permanent, and perhaps institutionalized production system in which producers depend on extra-household exchange relationships at least in part for their livelihood, and consumers depend on them for acquisition of goods they do not produce themselves" (but see; Flad and Hruby, 2007, p. 5). Furthermore, specialization is not a "single organizational state or present/absent condition," but rather that it occurs in degrees and may appear as any of several different types, with both the degree and type of specialization being influenced by the variables of context, intensity, scale, and concentration (Costin, 1991, pp. 3–8). It is these variables, then, that define the organization of production for a specific cultural milieu - the locus of activity for the enactment of technological style.

For technological style, *context* is perhaps the most influential of the four variables, referring to the affiliation of producers and, by extension, the nature of demand for their wares by virtue of differing tastes and goals among varying classes of individual (Brumfiel and Earle, 1987, pp. 5–6; Costin, 1991, pp. 5, 11–13; Costin and Hagstrum, 1995, pp. 620–621). Most frequently, affiliation is described in terms of attached vs. independent, the former describing individuals working for an institution, such as the palace, and the latter being those artisans producing for a general population (Brumfiel and Earle, 1987, p. 5; Costin, 2001, p. 276, 1991, pp. 5–11; Costin and Hagstrum, 1995, p. 620). In a general sense the goal of the attached specialist is to produce items significant in the local political economy (cf. S. T. Childs, 1998), while the independent specialist tends to supply utilitarian goods such as tools or cooking utensils (Brumfiel and Earle, 1987, p. 5; Costin, 2001, pp. 276–277, 1991, pp. 11–12; Flad and Hruby, 2007, pp. 9–11). As such, the primary concerns of the independent specialist will be with efficiency and the minimization of production costs while a patron will largely dictate those of the attached specialist.

Closely linked with context, the *intensity* of specialization describes the amount of time spent working at a productive endeavor, generally on a continuum between full-time and part-time. Most discussions of intensity describe gains in productive efficiency accruing from routinization of productive processes and greater investment in technology, assuming a local market that generates both sufficient demand for specialist goods and can provide adequate subsistence products in return (Brumfiel and Earle, 1987, p. 5; Costin, 2001, pp. 280–281, 1991, pp. 16–17). For this reason, Costin (2001, p. 280) has noted that full-time specialization is unlikely to have existed in the pre-industrial world due to inherent instability in subsistence markets, leading to the inclusion of scheduling in considerations of intensity. What this means is that the intensity of production will vary throughout the year as craft specialists engage in other activities (i.e. farming) to ensure their subsistence needs (Childs, 1998, pp. 112–113; Costin, 2001, p. 280). This being said, however, important caveats must be made for various types of attached specialist, where we do in fact seem to see evidence for full-time production, particularly in Mesopotamia (Zaccagnini, 1983).

A partial corollary of intensity is *scale*, generally defined as the composition of the production unit based on the criteria of size and principals of recruitment – in other words, the number of people in a production unit (Costin, 1991, p. 15). In the case of independent specialists, this is determined by the benefits derived from economies of scale in the realms of efficiency and cost sharing (see also, intensity), while for attached specialists scale is more heavily influenced by logistical and administrative concerns accruing to the patron. Principals of recruitment are an equally amorphous concept, covering a wide variety of configurations including family-operated endeavors, contractual employment, or enslavement. As such, though it certainly has a great impact on how a production unit might be organized, there is little to suggest that it is clearly linked to the context of specialization, being rather a general descriptor for the output volume per individual in a workshop (Brumfiel and Earle, 1987, p. 5; Costin, 1991, pp. 15–16; Costin and Hagstrum, 1995, p. 620). Determinations of scale in archaeological contexts, failing textual sources providing specific numbers, are limited to relative categorizations based on the extent of archaeological remains, making any judgement dependent on concentration. This is particularly problematic at Alalakh where workspaces appear to have been regularly cleaned, meaning that while contexts can be compared to one another, it is almost impossible to suggest an absolute scale.

The final parameter, *concentration*, refers to the actual geographical distribution of specialists within the landscape (Costin, 1991, pp. 13–14; Costin and Hagstrum, 1995, p. 620). Fundamentally, this dispersal is shaped both by the variables laid out by Costin, as well as various cultural and environmental considerations. As a result, it becomes crucial to evaluate the patterning of activity areas seen on- and off-site in the archaeological record in relation to relevant environmental factors such as the distribution of raw materials, or cultural influences such as state control over valuable resources and the deployment of sumptuary laws. In addition to these features, questions of transportation capacity also take on significance where factors of weight, bulk, and distance suggest that producers of heavier, larger goods will generally be more distributed to minimize transport costs.

Costin goes on to note a number of other factors important to shaping concentration patterns such as the presence of regular markets and synergistic nucleation where technologies shared between specializations may result in what appear to be mixed production units, however, these are factors that are case specific and do not apply in every situation. For attached specialists, the observation is made that one of the primary factors determining the degree of nucleation will generally be the need on the part of patrons to control “raw materials, technology, the quality of output, finished inventories, and final distribution” (Costin, 1991, pp. 14–15). As such, attached specialists are assumed to operate most frequently as nucleated production groups. However, because concentration, like context, intensity, and scale, operates on a continuum and because a given individual may occupy more than one position on such a continuum, there are always exceptions to these generalizations.[10]

Having discussed those elements of specialization that structure the organization of production, there remains a question of what the material correlates of specialization look like. Costin (Costin, 1991, pp. 18–20) suggests that the hallmark of specialized economic activity is variability, manifested materially as “differential distributions of the materials and artifacts

[10] In the case of Toro ironworkers, for example, the concentration is generally dispersed based on proximity to raw materials despite short transport distances and the presence of formal marketplaces. Furthermore, attached specialists producing goods for the king also operate as independent specialists but nevertheless remain in a dispersed concentration even when working in their official capacity (Childs, 1998).

associated with production" and may appear, depending on scale, as highly localized variation within a single structure, all the way to large-scale variation within settlement systems (Costin, 1991, p. 4). Considering this, we now have a circumstance where specialization leads to variable patterns in material assemblages, the precise character of which is determined by the interplay between technological style, organization of production, and patterns of consumption. In this case, we may refer back to the relatively decentralized and highly specialized contexts of iron smelting and blacksmithing at Tell Hammeh and Tell Beth-Shamesh discussed by Veldhuijzen (1999) which takes place within a broader context of relatively limited state control. By contrast, the situation at 5$^{th}$ millennium BC Değirmentepe points to an administratively controlled, nucleated, but not particularly specialized system of copper production by virtue of a completely mixed assemblage of metallurgical debris across the site (Yener, 2000).

Since the publication of Costin's (1991) seminal work, there has been a general paucity of literature that seeks to directly build upon or critique the foundations laid out in that article – many of them being written by Costin herself (Costin, 2007, 2005, 2001, 1998, 1991; Flad and Hruby, 2007). Looking at the development of her ideas over the course of almost 30 years, it is clear that they have shifted from the analysis of specialization as a specific mode of productive activity on the basis of precisely defined components to a more general concern with production structured by loosely defined heuristic categories (Costin, 2007, p. 150). A key example of this lies in the progressive broadening of context from producer affiliation to the "general conditions or circumstances in which production occurs, including the physical environment in which production takes place and the social, political, economic, and ideological milieus that structure relations among producers and between producers and consumers" (Costin, 2007, p. 150, 1991, p. 11). What this represents, to my mind, is a general acceptance that the range of possibilities for structuring productive systems is so varied that, while we do need to have a common vocabulary for discussing what we are studying, saddling that vocabulary with overly-prescriptive definitions runs the risk of making the study of ancient production impossible. In short, there is a need to evaluate production in specific contexts, without preconceived notions about what modes of organization we are liable to encounter.

Regarding Flad and Hruby (2007), I will limit my commentary to a few statements, as I am largely in agreement with Costin (Costin, 2007, pp. 147–150), finding many of the proposals unhelpful in their lack of clarity and utility, while the focus on elite goods rendered the range of inquiry too narrow and serves only to entrench inherent bias as discussed above. One notable exception in this respect was the call to consider what it is about certain crafts that makes them elite or non-elite, what renders something a necessity, and the context-dependent nature of value and meaning. I find this intriguing because it raises questions about when in a productive process a type of knowledge becomes esoteric enough to be considered valuable, mechanisms for reconciling the prestige value of materials with their production by seemingly unremarkable individuals, and the need to consider that in many ways, groups of producers constitute societies unto themselves.[11] Recent work by Costin (2016) in looking at the role of *tekhné* reveals an increasing concern with these topics and, incidentally, is a vital step in determining what makes specialized production a viable productive strategy.

## 2.3 Operationalizing Technology

The overarching theme of the previous discussions has been that technology and culture are in no way separable entities. Instead, it is useful for us to envision technology as a descriptor

[11] The development of profession-based ethnic groups such as the iron smelting Agaria could be taken as an extreme example of this (cf. Elwin, 1942b).

of how members of a society interact with and think about materials and how those interactions are structured. Because power and influence are often linked to the manipulation and control of socially significant types of matter (vis-à-vis Helms, 1993b), as a material becomes more socially valuable its associated technology should more closely reflect significant cultural ideas and power systems, while divergences or idiosyncrasies may be understood as elements of resistance. In the broader Near East, the textual record often reflects a significant preoccupation on the part of elites with managing metal resources and associated personnel, not to mention idealized descriptions of control systems and cultural ideals (Lehner, 2015; Waetzoldt and Bachmann, 1984; Zaccagnini, 1983; Sasson, 1968). It is the fact of this consistent and intense interest that tells us that the study of Near Eastern metallurgical technologies has much to say about the relationships between people, things, and power. It is, however, only possible to tease out these relations by utilizing a fine-grained approach, lest we miss both broad trends and small divergences.

Despite the clear utility of this perspective, much research on ancient metallurgy has been dominated by studies approaching the topic from the perspective of metals as aesthetic objects or hardware, or metallurgy as applied science, resulting in a disconnect between technical evaluation and cultural context.[12] Furthermore, many studies tend to operate primarily at a broad scale of analysis that is more concerned with sweeping generalizations than detailed characterization. The result has been narratives hinging on topics such as widespread adoption of

[12] For an example of metals as object, one may consider Stronach (1957) or Stech and Pigott (1986). The former is distinctly borne from an art-historical tradition while the latter takes metals as a generalized object of trade. For metallurgy as a scientific technology, Maxwell-Hyslop and Hodges (1966) or Muhly (1985) are excellent examples. The former is focused on the techniques of iron working, while the latter takes a more general assessment of its role in the Hittite Empire. Of course, in this division we may also see a reflection of the rupture caused by the development of processual archaeological methods and theories.

alloy types, elucidation of interregional exchange networks, and development of technologies for mass production. While these perspectives often tell us a great deal about how large political entities utilized the products of technical processes, they do not reveal much about the locally specific technological foundations supporting their exercise which rendered them capable of supporting such political entities. As a result, we also miss a wealth of information on how these interactions produce change at the micro and macro levels. To complete the picture, we also need some idea of how individual workshops functioned within urban centers, what networks they tapped into for raw materials, who they produced goods for, what their technical capacities were, and what other activities they may have engaged in. This information has the potential to inform us about urban landscapes of production, the point of articulation between long-distance trade and consumption, and generally how elements of sociotechnical systems fit together.

Currently, there are several major foci in studies of Near Eastern metallurgy that have begun to work against this oversight. The first of these is the question of how production was organized and what stimulated development towards larger-scale industries (Helwing, 2017; Rademakers et al., 2017; Vatandoust et al., 2011; Yener, 2000). The second is intentionality of alloys, with a particular focus on arsenical bronzes and specific use contexts of different materials (Boscher, 2016; Hauptmann et al., 2003; Rehren et al., 2012; Thornton et al., 2009). Third, the development of iron metallurgy as a regularized process, thought to have occurred during the LBA, which finally allowed metals to have an extensive social impact (Bunimovitz and Lederman, 2012; Cordani, 2016; Erb-Satullo and Walton, 2017; Muhly et al., 1985; Souckova-Siegelová, 2001). Finally, largely stemming from work on Cyprus, there is the question of when intentional slagging processes in copper production became widespread, allowing for increases in productive efficiency and volume (Bachmann, 1982b; Muhly et al., 1980; Stos, 2009). The range of concerns addressed by archaeometallurgy extends far beyond these limited points, but these studies represent those most relevant to the concerns expressed here.[13]

Though limited in terms of technical discussions, the Hittite textual repertoire represents one of our best sources for accessing some aspects of the cultural contextualization of metals. Of import are mentions of their acquisition and distribution through systems of taxation, as well as their deployment in a range of significant ritual contexts. The archives of Mari, Ebla, and to a lesser extent Mesopotamia, provide complementary accounts of metal resource management and labor organization that is often missing from other bodies of written evidence. These sources provide insight into quantities of metals in circulation, how they were being processed, and how idealized management systems varied across space and time in the Near East. Because these sources cover several millennia and a wide geographical span, it would be naïve to overstate their reflectance of organizational and cultural principals at Alalakh, particularly given the now well-known preservation of local cultural traits through the periods of heightened foreign influence (Yener, 2017). Nevertheless, what these texts do provide is a signpost for the interpretation of archaeometrically and archaeologically derived patterns in the material assemblage.

In this respect, it is crucially important that Tell Atchana has yielded its own significant archives as material for comparison. With these, as well as texts from Syria, central Anatolia, and Mesopotamia, we may begin to discuss the place of artisans in the ancient Near East. The Level IV archives of Tell Atchana provide a richly detailed discussion of class stratification and

[13] For a broader overview of current trends in archaeometallurgy, see; (Thornton and Roberts, 2014)

territorial management in the Amuq Valley.[14] Such a perspective is essential if we are to consider metallurgy as a sociotechnical system with far reaching manifestations beyond the city walls. Texts from neighboring regions and different time periods act as both a complementary and comparative dataset to those from Atchana. Here, we see a great concern with acquiring and keeping track of skilled metalworkers and their activities, while also keeping in mind that, as a region with no local metal resources, the use and perceptions of metal technologies in Mesopotamia are liable to be fundamentally different from those at Alalakh. Access to raw materials not only impacts logistics, it also potentially affords access to populations with long-term experience exploiting those resources before urban societies developed a significant interest. This is especially important when considering the concentration, scale, and intensity of production as seen in the archaeological record, since both sets of textual data can help provide a cultural explanation for observed patterning in metallurgical remains.

The preceding discussion leads now leads us into my more specific research questions. During the Middle (MBA) to Late Bronze Age (LBA) transition in the Near East, state power underwent significant developments allowing for the creation and integration of large territorial empires. One impact was the entrainment of balkanized metallurgical traditions of the Chalcolithic and Early Bronze Age (Yener, 2000) in support of the emergent wealth-finance systems of these entities (Lehner and Schachner, 2017). Similarly, increased metal production afforded by technical advances allowed for broader circulation of metals and a shift in their importance from the socio-political realm to the economic.  I suggest one outcome of these

[14] Akar and Kara (2018) have recently used this information to discuss land tenure in the Amuq going back to the Middle Bronze Age in light of recent excavations at Toprakhisar Höyük, near Tell Atchana.

changes was increased centralization and integration of metal production processes[15], representing a significant technological shift from previous periods. If this is the case, the next step is to investigate whether the primary motivation behind these processes came from the state or broadening market structures. In other words, was state sponsorship a critical force in the development of complex industry, or did it develop organically in response to increased generalized demand? These questions directly address the footprint of state power in the LBA, drivers of technological change, and the broader debate between public-private economic spheres in the LBA.

I address these larger intellectual ambitions by answering three specific questions: (1) <u>What technical practices characterize the metallurgical assemblages of Areas 1 and 4 of Alalakh?</u>

At Tell Atchana, Area 1 represents a palatial and temple complex, while Area 4 represents a non-elite craft quarter. During the LBA, two major advances in metallurgical technology occurred. The first of these was the development of improved fluxing techniques and higher furnace temperatures, allowing the formation of less viscous slags, resulting in increased production volume. Thus far, direct evidence for this development is largely limited to Cyprus (Bachmann, 1982b; Muhly et al., 1980), with investigations of LBA primary production in the broader Near East sorely lacking (Lehner and Schachner, 2017). This said, it is well-established that metal circulation increased during the LBA, and current thought suggests that this increased the availability of metals to non-elites, with 'fresh' metals and rare alloying components

[15] The reader should be aware that, as noted in the introduction, many of the hypotheses here and below were developed to be tested by the analytical phase of the project. They are flawed on a number of levels and points where they have proven incorrect or unfounded are discussed in chapter 10.

remaining elite materials, and recycled metals going to average people (Routledge and McGeough, 2009; Sherratt, 2016; Stos, 2009). A lack of detailed investigations from LBA secondary production workshops means that the general reality of this situation is uncertain, and it is not entirely clear how this increased circulation affected the prestige status of metals. The second major development was increased production of iron, with much evidence for this being drawn from textual sources (Cordani, 2016; Muhly et al., 1985; Yalçın, 2005). One potential explanation is that advances in copper smelting techniques allowed for production of iron as a byproduct (Craddock and Meeks, 1987; Erb-Satullo, 2019). This set the stage for its deliberate production during the Iron Age (IA), when metals moved out of the elite realm and began to make significant contributions to arenas such as agriculture and warfare.

(2) How does the organization of production manifest within the city of Alalakh?

Stemming from technical advances in metallurgy and a broadening economic base supporting metallurgical activity during the LBA, the ways labor was organized may have changed significantly. During the preceding EBA and MBA, metal production was organized in a two-tiered system, with highland sites carrying out primary production while secondary production was focused in lowland population centers (Lehner and Yener, 2014; Yener, 2000). According to this model, highland sites were typically independent, operating outside of state control, while the exact status of artisans in lowland settlements appears to have been highly variable (Sasson, 1968; Stein and Blackman, 1993; Wattenmaker, 1998; Zaccagnini, 1983). A similar arrangement has been suggested for the LBA, but the lack of primary production contexts and in-depth studies of secondary contexts means that organizational models for this period remain unclear (Lehner and Schachner, 2017). Two notable exceptions regarding primary production are Cyprus and Transcaucasia, however, they each represent completely different modes of organization, emphasizing the need for locally specific narratives (Bachmann, 1982b; Erb-Satullo et al., 2017). Furthermore, the dominance of palatial economies in the economic landscape of the LBA, which controlled most productive activity within their domains while trading extensively with other kingdoms, is a further significant factor. The question of whether expanding metallurgical activity occurred because of independent entrepreneurship or under palace administration has significant implications for the level of direct control palaces could exert over their surrounding landscape at distance, the capacity of the state to control skilled labor, cooperation between private and royal enterprise and the general distribution of metals. Given this confluence of factors organizational patterns must not be assumed, they must be demonstrated.

(3) What is the cultural representation of metals and metal technologies in the Near East and how does that compare to the archaeologically derived picture?

The MBA was a period when the state entities that dominated the political and economic scene during the LBA began to crystallize (Akar and Kara, 2018; Frangipane, 2010; Magness-Gardiner, 1994, p. 42). The textual records of these periods, as well as those of the EBA and IA, represent the idealized views and economic logics of a durable elite that has been studied in-depth for over a century. Archaeological and archaeometric perspectives have the potential to identify dissonances between these logics and the broader situation revealed in the archaeological record. Therefore, comparison of results stemming from the two above questions with the textual record has the potential to aid in the identification of ways in which elite visions were enacted, as well as ways in which they were challenged.

Taking these questions as our foundation and considering them in light of the above discussion, we can then lay out several expected outcomes relevant to each:

Question 1:

Evaluation of technical processes in each area provides us with an accounting of the range of techniques employed by local artisans to meet the needs of relevant social groups (see below). If we follow currently dominant narratives in archaeology, the metallurgical assemblage of both areas should be limited to secondary production activities signaled by crucible slags, various tools, relatively small pyrotechnical installations, and casting spill. Further, we should expect to see a minimally trimodal distribution in metal compositions representing raw metals, alloys produced from raw metals, and recycled metals, with Lead Isotope Analysis (LIA) then suggesting the likelihood of imported metals. If there is evidence for primary production, we need to adjust our application of Yener's (2000) two-tiered production model for the LBA context and, further, consider how well that evidence supports current narratives of technological development, including possible indications of iron production. Any re-evaluation of this hypothesis depends heavily on the character of any additional compositional modes. Finally, if metals are supposed to have lost a certain degree of prestige value, then an increasing proportion of the assemblage should be composed of utilitarian goods potentially produced with a lesser application of skill.

Question 2:

An answer to this question will come from archaeometric data and spatial analysis. Assuming no evidence for primary production, the chief points to consider are industry management and distribution of metals. If the industry is largely managed by the palace, the assemblages from both areas should be largely the same in terms of composition, technical signatures, and artifacts produced as a result of a limited clientele and shared provisioning networks. I would also expect to see increased specialization manifested as decreased material variability within workshops (routinization), but increased variability across the site. Finally, workshop assemblages in this case should show a minimum of recycled material. If these expectations are largely in-line with current thought regarding the organization of secondary production, then all workshops in the city should appear as palace-operated, with independent artisans being largely itinerant (Stos, 2009). If there is both private and palace-operated industry, private workshops should manifest with a higher proportion of recycled material and a generally lower degree of internal specialization stemming from the need to serve a broader population, while royal workshops would potentially show significant internal specialization or specialization between workshops and a larger proportion of 'fresh' metal and rare materials. There is, finally, the possibility of workshops serving both royal and general populations, in which case the level of internal specialization is likely to be low, with a large variety of metal compositions present in individual workshops. Such a situation would indicate a significant capacity for artisans to negotiate beneficial economic arrangements indicative of a high level of prestige. If evidence for primary production is present, then we have a significant departure from previously suggested models of organization for Anatolian metallurgy that will require careful consideration and further study. If compositional analyses and LIA show a direct link between raw metal from primary production and finished goods from the palace area, with metals from non-elite areas showing a clearly divergent compositional and LIA signature, we may suggest directly controlled palace production. The extent to which primary production is agglomerated with other palace infrastructure may serve as a proxy for the level of state control of labor, while textual evidence will provide further support. If it appears that the metals produced have a wide distribution encompassing elite and non-elite contexts, an argument can be made for independent or semi-independent production, while the ratio of potentially traded metal to local production may serve as a general indication for production intensity. In either case, if primary production is present, future research directions would include additional excavation to gain a better picture of variation in workshop activities, while field survey for local mining zones would reveal much about raw material procurement.

Question 3:

Part of what we are looking for here is correspondence between textual accounts of organization and that shown in the archaeological record, as it provides some measure of the efficacy of state control. That is, texts reflect an idealized reality while the archaeological record reflects actual actions. The comparison of texts with results from the previous two questions speaks to this question and points of dissonance are of particular interest as they represent potential attempts to dissociate the technological system or to manipulate it toward other goals (Pfaffenberger, 1992, p. 510). A greater degree of administrative oversight visible in the archaeological material, for example, could be indicative of more conservative ideas surrounding the deployment of metals. Whether that conservatism is overtly linked to economy, ritual, or social convention is a question of context, such as greater controls being placed on silver or copper circulation as they become entrained in monetary systems. Similarly, in some Mesopotamian texts (Moorey, 1994, pp. 272–273, 276) significant cultural weight is given to skilled craftsmanship, for which the relative degree of specialization can act as a proxy, reinforced by indicators of process control and mastery seen archaeometrically.

In the preceding discussion, I have laid out the theoretical underpinnings of this study and my primary research questions with an eye towards explaining the character of technology and socio-technical systems and their relationship to the notions of technological style and craft specialization. A key point of this has been the notion that technologies extend well beyond the hardware and natural scientific constraints governing technical practice, being heavily influenced by the social goals of production and culturally specific ways of structuring productive action. Because of these concerns, we may reasonably suggest that the patterning of archaeological remains is indicative of these ways of structuring productive action, while the textual record provides some insight into the social goals of production. Finally, in as far as any artifact is a result of choices made in the course of a technical process, data acquired through the archaeometric investigation of metallurgical debris is indicative of how ancient artisans chose to meet the needs of consumers within the bounds of their own technological style. In Chapter 4, I will discuss recent research on Near Eastern metals and metallurgy from the Early Bronze Age to the end of the Late Bronze Age, the associated textual corpus, broader political developments at this time, and the place of Alalakh in the Late Bronze Age milieu.

# 3 Archaeological Background and Contexts[1]

Located in the Hatay province of southern Turkey, at the southern end of the Amuq Valley where the Orontes River makes its westward bend to the Mediterranean, Tell Atchana has a long-lived and highly significant history of scholarly investigation. Formal documentation of the site (AS136) was made under the auspices of the University of Chicago's Syro-Hittite expedition, led by Calvin W. McEwan during their regional survey of the Amuq in the spring of 1936 (Braidwood, 1937, p. 34). That same year, Sir Leonard Woolley, working at the behest of the British Museum, began excavation at both al-Mina – located at the mouth of the Orontes – and Tell Atchana. The Woolley excavations continued until 1939, and then were resumed from 1946-1949. In 1995, Prof. K. Aslıhan Yener launched a new round of Oriental Institute investigations with the Amuq Valley Regional Project (AVRP), initially investigating gold mines at Kisecik, revisiting the earlier Oriental Institute excavations at Tell al-Judaidah, and conducting surface survey of Tell Kurdu (Yener and Wilkinson, 1997). In 2000, Prof. Yener and her team began intensive survey at Tell Atchana and in 2003, initiated a new series of excavations at the site. In the present chapter, I will begin with a brief review of the results from the Woolley and Yener campaigns up to 2006. I will then follow this with a detailed treatment of the archaeological contexts from which I selected samples, which were excavated between 2007 and

[1] In the following discussion, I follow the convention laid out in the new series of Alalakh publications regarding identification of archaeological levels. That is, when referring to phases discussed by Woolley, they are referred to as "level" followed by the appropriate number as a roman numeral; when referring to material from the new excavations I use the term "period" followed by the appropriate number as an Arabic numeral. When referring to area-specific phasing, the term "phase" will be used, accompanied by the appropriate number as an Arabic numeral.

2017. This includes the entirety of Area 4, as well as Area 1 trenches 32.53-54, 42.10, and 42.29 (Figure 3-3).

## 3.1 The Woolley Campaigns

To look at Woolley's account, the excavation of Tell Atchana was as much a matter of luck as it was thoughtful planning. After the conclusion of his work at Ur in southern Mesopotamia, the board of trustees of the British Museum commissioned Woolley in 1935 to undertake a new project. With an eye toward investigating links between the Aegean and the mainland of the eastern Mediterranean, he settled on the region of north Syria because of its affordance of natural harbors and access to overland trade routes. With these considerations in mind the Amuq valley seemed ideal, with access to the Mediterranean via the Orontes River and to the inland via the Beqaa Valley, Belen Pass, and the North Syrian Plain (Woolley, 1955, p. 1, 1937, pp. 1–3, 1936, pp. 125–127). Though these considerations were generally well founded, the selection of Tell Atchana as a site for excavation was based largely on assumptions regarding its character derived from its size and shape, being low and oblong, which apparently suggested the presence of a palace, giving the choice a somewhat arbitrary feel (Woolley, 1936, p. 128). Due to the uncertain merit of the proposed project, the board of trustees demurred to fund Woolley's expedition for the 1936 season. Fortunately, Sir Neill Malcom, a former British Army officer, put together a fund to finance the expedition, still in the name of the British Museum (Woolley, 1955, p. 1).

The first season of excavations in 1936 focused primarily on what Woolley thought to be the main port feeding into the Amuq Valley from the Mediterranean; the site of Tell Sheikh Yusuf, located in the town of al-Mina at the mouth of the Orontes. Upon excavation, however, he found that the earliest levels of the site could only be attributed to around the 8$^{th}$ century BC, as suggested by finds of geometric pottery, while he surmised that earlier material must have been washed away by the river (Woolley, 1937, p. 10). Recent research has shown that during the Late Bronze and Early Iron Age, the current location of Tell Sheikh Yusuf would have been under water, meaning that Woolley's initial assessment was incorrect (Pamir, 2013, p. 174). In this respect, the exploratory excavations carried out at Sabuniye in 1936, located just up the Orontes from al-Mina, are significant. Though the Woolley exposures were quite small, they did unearth Late Bronze Age Cypriot and Mycenaean pottery of types frequently found inland, while limited excavations conducted by the Orontes Delta Archaeological Project in 2008-2009 have yielded such finds as a scarab dated to the reign of Thutmosis III (1479-1425 BC) (Pamir, 2013, pp. 175–176; Woolley, 1938, p. 9). Thus, it seems most likely that the settlement at Sabuniye was the port connecting the Amuq with the Mediterranean and Aegean. Finally, it was also during this 1936 season that Woolley was able to excavate a series of exploratory trenches in the summit of Tell Atchana. Here he was able to uncover a variety of remains including substantial architectural features destroyed by fire as well as ceramic material with Minoan and Mycenaean characteristics (Woolley, 1936, pp. 130–132). The finds from that season, which signaled the possibility of connections between north Syria, Anatolia, the Aegean, and Mesopotamia, secured his interest in the site, as well as that of the board of trustees at the British Museum, leading to the subsequent years of excavation.

Woolley was able to identify seventeen levels of occupation at Tell Atchana dating from the late third millennium BC to the end of the thirteenth century BC.[2] The earliest stages of this

[2] This dating identifies Woolley's Alalakh XVII and Braidwood's Judaidah XII as being contemporary based on the presence of Jemdet-Nasr ceramics (Woolley, 1955, p. 379). Unlike Alalakh, however, Tell al-Judaidah appears to be one of the few large sites in the Amuq that remains occupied through the LB-IA transition.

period, represented in levels XVII-VIII, are limited largely to the Middle Bronze Age, with a tentative end around the 18th century BC. These levels were explored in two deep soundings, one at the southern end of the level VII palace and the other being the infamous temple sounding. The former was only excavated to level XVI before water encroachment made it infeasible to continue work. For the latter, Woolley used a pump to remove the water and excavate down to virgin soil, however, by his own admission, the results were less than satisfactory (Woolley, 1955, p. 35). Furthermore, because the temple sounding stratigraphy was, and remains, decoupled from the rest of the excavations,[3] the details of how the temple sequence fits within the development of the site remain enigmatic. The remaining levels, VII-O, which run from the late 18th/early 17th century to the end of the 13th, have the largest horizontal exposures, covering much of the northwestern tip of the mound (Figure 3-1), encompassing palaces, temples, and so-called "private houses."

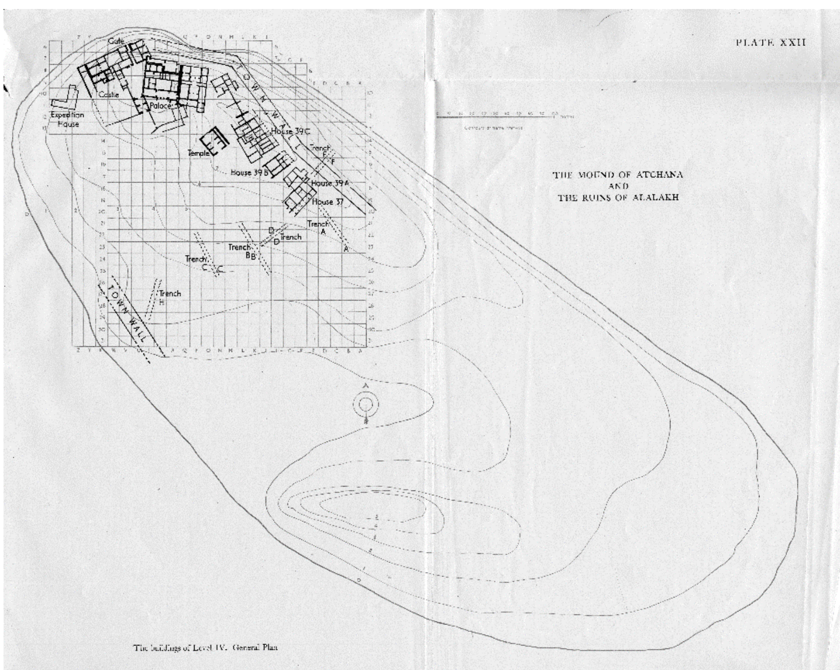


Figure 3-1: General Plan of the Woolley excavations at level IV, also illustrating the widest extend of the excavation exposure. (Woolley 1955, Plate XXII)

The level VII and IV palaces were excavated almost in their entirety. Starting from the earliest traces, it seems that the precursor to the level VII palace first appears in Woolley's level XII as a structure of unusual

[3] With the exception of the level VII temple, which was directly joined to the level VII palace complex (Woolley, 1955, p. 91).

importance, being of a scale well beyond that of previous levels and outfitted with a substantial colonnade (Woolley, 1955, pp. 17–25).[4] The intervening levels XI, X, IX, and VIII exhibit a similar palatial character, according to Woolley's account. The level VII palace was probably constructed around 1710 BC when Yarim-Lim began his reign at Alalakh and was most-likely destroyed by Hattušili I sometime in the 1570's BC, when Yarim-Lim's son Ammitaqum occupied the throne (Bryce, 2005, p. 71; Mullins, 2010, p. 61; Yener, 2005, p. 101).[5] The palace occupies a space of roughly 100x30m situated against the city wall, which formed the eastern side of the structure. Within this space, Woolley identified two distinct wings of the palace. According to his estimation, the northern half of the structure was given over to official functions with a second story that hosted the living quarters of the royal family (Woolley, 1955, pp. 91–94), while the southern portion was largely dedicated to domestic purposes and the palace staff (Woolley, 1955, pp. 95, 98).

The structures of the intervening levels VI and V are only poorly known from a few soundings that Woolley was able to conduct beneath the level IV Palace and those portions of the level V structure that were incorporated into the level IV building. By all accounts, however, these were substantial edifices and Woolley goes so far as to identify them as palaces (Woolley, 1955, pp. 111–112). Using Woolley's description as our foundation, the level IV Palace seems to have been constructed in several different phases during the reign of Idrimi and his successors, Niqmepa and Ilim-Ilimma, ranging between 1460-1400 BC (Yener et al., 2019a; Yener, 2005, p. 102; Woolley, 1955, pp. 111–112). The new block, occupying a space of about 33x30m and

[4] This must be taken with the caveat that the exposure of the level XII building was too small to reveal the structure's true character.

[5] There remains substantial debate regarding the absolute dating of events during the 2$^{nd}$ millennium BC, which is well beyond the discussion to be presented here. Note, however, that the dates used here are derived from the Middle Chronology.

attributed by Woolley to Niqmepa, was probably actually constructed by Idrimi as the founder of the new dynasty. In order to build this structure, the northwestern portion of the level V palace was cut away and the new structure erected on a decidedly different orientation (Figure 3-2), apparently determined by the trajectory of the northwestern city wall (Woolley, 1955, p. 111). The subsequent additions, which I hesitate to ascribe to one ruler or another, were a substantial eastern wing erected over part of the old level VII palace, as well as a northern wing that filled the space between the city rampart and the palace's northern wall.

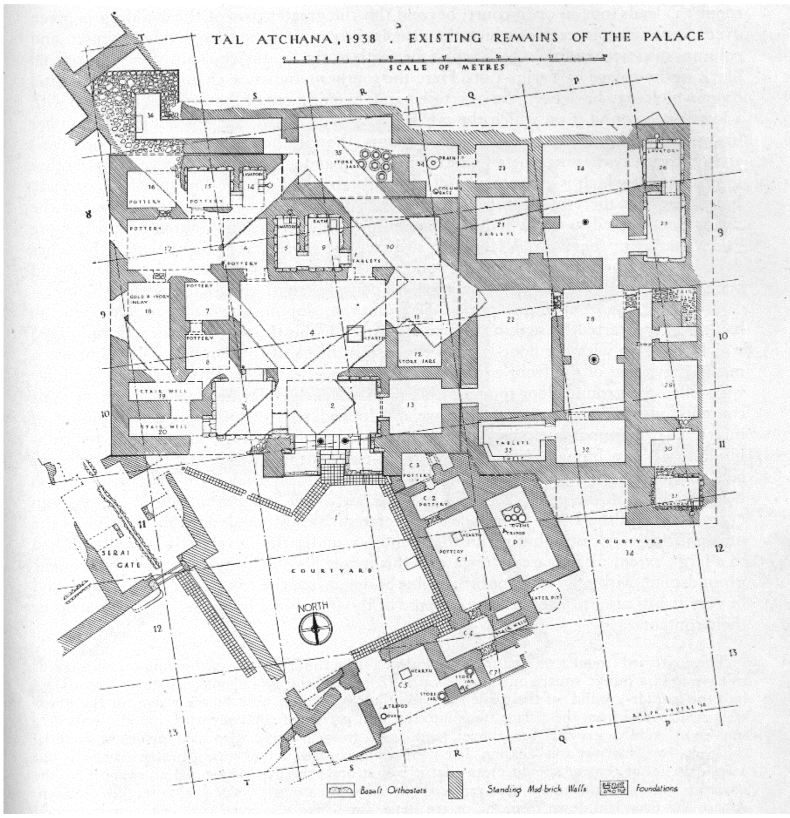



Figure 3-2: View of Level IV Palace with remaining Level V structure. The point of articulation between the Level V and Level IV structures is mostly in square R11. The delineation between the original structure and the eastern and northern wings runs roughly at the line between columns R and Q and rows 9 and 8, respectively (Woolley 1955, 113).

The primary temple at Alalakh was located immediately west of the level VII palace and southeast of the level IV Palace, forming a consistent center around which the royal precinct was constructed. That the location of this temple, attributed to the worship of Ishtar, remained in the exact same location over the course of seventeen levels spanning almost an entire millennium is indicative of the consistency of cult practice at the site and the importance of place (Yener, 2017). Unfortunately, as I mentioned previously, the temple sounding was physically detached from the remainder of the excavations, meaning that the phasing of the temple is detached from the rest of the site. In this respect, it seems that only levels XVI and VII can be connected to the broader site with any certainty, the former being linked to Woolley's other deep sounding on the basis of elevation, while the latter is directly attached to the level VII palace (Woolley, 1955, pp. 33, 91). At the root of this issue is that fact that, between these two levels, only five clear structures are present as a result of the temples being important cult buildings that were maintained over long periods of time and often renovated rather than destroyed and rebuilt. The subsequent level VI temple was almost completely destroyed, supposedly during the construction of the level V temple, which itself was of a very unusual character, lending an air of ambiguity to the discussion of their phasing (Woolley, 1955, pp. 65–71).[6] Meanwhile, in the following levels IV-I, dissociation of the various temple remains and evaluation of their stratigraphy has proven difficult and remains an area for on-going research (Batiuk and Horowitz, 2010; Woolley, 1955, pp. 71–90).

In similar fashion to the temple sounding, Woolley's "private houses" generally lack a direct physical link to other areas of the excavation, making their phasing a matter of question (Yener, 2013, p. 17). When we consider that these structures had a generally shorter lifespan and underwent more frequent remodeling than royal and cult buildings, the issue is further compounded (Woolley, 1955, pp. 171–173). Overall, it appears that the private houses were distributed between levels IV-I, though Woolley also attributes the structures from levels XII to XVI in the level VII palace deep-sounding to this category as well. Most of the remains were arrayed to the southeast of the level VII palace, along the city wall, and generally display

[6] The underground nature of the level V sanctuary led Woolley to speculate that it may have been an early example of a Mithraeum, by virtue of the Mitannians having supposedly introduced Mithras to the eastern Mediterranean (Woolley, 1955, p. 69).

excellent quality of construction while the assemblages included substantial storage vessels as well as libation vessels, precious metals, cylinder seals, and other objects of value (Woolley, 1955, pp. 177–178). Taking this into consideration, along with the proximity of these structures to the palace and temple and the textual attestation of the worship of other deities aside from Ishtar at Alalakh, Yener's (Yener, 2005, p. 109; Yener and Yazıcıoğlu, 2010, p. 29) suggestion that these are part of a broader temple complex gains considerable currency.

## 3.2 The Yener Campaigns

One of the most substantial problems with Woolley's campaign originated with the disjointed nature of the excavation areas and over-simplified stratigraphic interpretation, resulting in problems with phasing and chronology (Akar, 2013, pp. 39–42). It was in response to this issue that the Yener excavations were launched in 2003 after several seasons of regional survey under the aegis of the AVRP. The primary goals of the new excavations started with the issue of refining and clarifying the stratigraphy and chronology of the site. After addressing this, further areas of interest included: consideration of the resurgence of urban societies during the MBA as reflected at Alalakh, an assessment of its contacts with societies to its northwest – particularly in Cilicia and on the Anatolian Plateau, illuminating the archaeological cognates of empire as seen at the site, and the processes by which palace economies collapsed at the end of the LBA (Yener, 2010, pp. 4–6). In addition to these more specific aims, the Atchana team has also placed emphasis on exploring areas of the mound beyond the royal and temple precincts and generating a broad series of interdisciplinary studies to augment our understanding of the site.

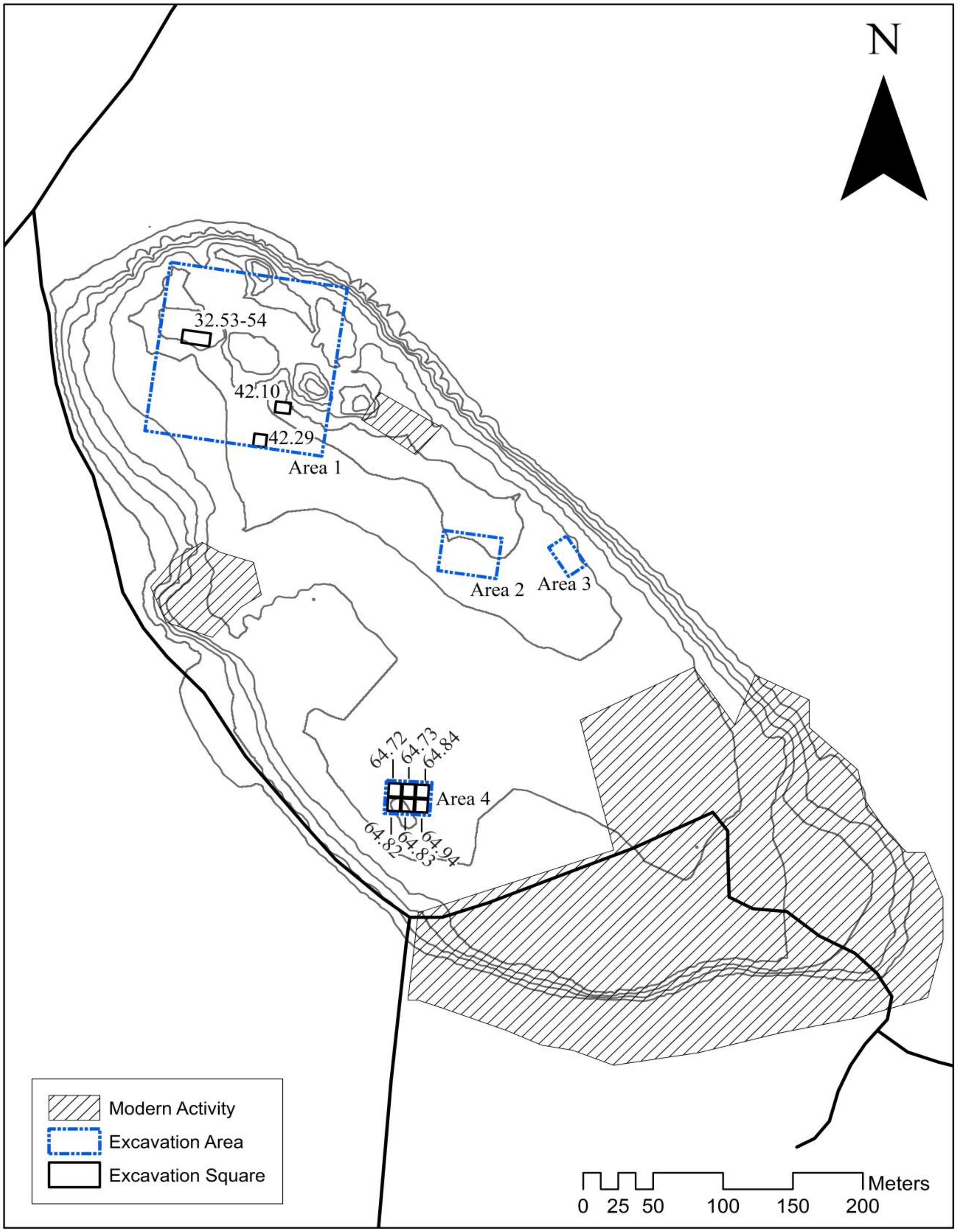



Figure 3-3: Excavation areas of the Yener campaigns and primary trenches used in this study. Contours derived from data provided by Murat Akar. © 2020 Alalakh Archives

Since 2003, new soundings have been opened in four excavation areas (Figure 3-3). Area 1 corresponds to the northwestern portion of the mound where Woolley conducted the bulk of his original excavations. Areas 2 and 3 are located along the eastern edge of the mound, roughly halfway down its length. Area 4 is located on a rise on the south side of the mound, near the edge of the modern village that occupies Tell Atchana's southern end.

Activities in Area 1 have formed the core of the effort to re-evaluate and adjust Woolley's original stratigraphy and phasing. Nine squares have been opened at various points within, adjacent to, and slightly removed from the original excavation area. In the initial 2003-2004 seasons, three squares were opened at the western end of Woolley's main cut, situated on the southeast side of the level III/II fortress (32.53, 32.63, and 32.54), originally attributed to the initial phase of Hittite occupation (Woolley, 1955, pp. 395–396). While 32.53 and 32.63 served to expand our understanding of the architecture of the Northern Fortress, 32.54, situated right at the interface with Woolley's excavation area, functioned as the main point of articulation for reconciling the new excavation stratigraphy with that of Woolley (Akar, 2019; Yener and Yazıcıoğlu, 2010, pp. 11–12). In subsequent seasons, this section of three squares was expanded to a total of six (32.52, 32.62, and 32.64 were added) in order to improve our understanding of the Northern Fortress and the underlying post-level IV stratigraphy. In addition to this block, trenches were placed in the courtyards of the level IV and VII palaces (32.57 and 33.32, respectively) with the goal of exploring the earlier phases of the site represented in Woolley's stratification pit and temple sounding (Bulu, 2016; Yener, 2015b). The ninth (32.59/60) was located between the level IV Palace and temple sounding but was abandoned when it became apparent that the area had been disturbed by Woolley's activities. Finally, as part of an effort to study the outer margins of the Royal Precinct, trenches 43.54 and 42.29 were started in 2007 and

2009, respectively, while 42.10 was situated between these trenches and the Woolley temple sounding in 2012 to clarify the stratigraphy of the temple.

Work in Area 2 (trenches 44.45, 44.46, 44.54, 44.55, 44.68, 44.69, 44.79, and 44.80), carried out during the 2003-2004 and 2011 field seasons, was primarily intended to provide a sizeable horizontal exposure beyond Area 1 and to provide a stratigraphic correlation with the Area 3 step trench (Yener and Yazıcıoğlu, 2010, p. 12). These excavations yielded two phases of occupation, which appear to be largely domestic and craft oriented. Phase 2, by far the better preserved of the two phases, seems reminiscent of Woolley's "private houses," appearing primarily as domestic units comprised of multi-room structures. Associated assemblages were quite diverse including glass, faience, copper-based objects, ivory, and slag (Yener and Yazıcıoğlu, 2010, pp. 12–16). Phase 1, with sub-phases 'a' and 'b,' seems to have been largely given over to craft production with an emphasis on pottery firing, based on the discovery of remains of what seem to be several two-story pottery kilns (Yener and Yazıcıoğlu, 2010, pp. 16–22).

Area 3 (trenches 45.71, 45.72, 45.62, 45.44 and 44.80), which represents a rather fascinating area of the site due to its baffling variety of depositional contexts, was initially started as a step square meant to reach down to the level of the crop fields. The goals in this area were twofold, focusing on identifying fortification systems at the site and their sequencing, and to aid in the development and refinement of a new stratigraphic sequence (Yener and Yazıcıoğlu, 2010, p. 24). Ultimately, this area has yielded four phases consisting of a substantial necropolis, including the much-vaunted plastered-tomb (Boutin, 2010; Yener and Yazıcıoğlu, 2010, pp. 27–28), as well as kitchen/workshop contexts and one phase of MBA city-wall.

Area 4 (trenches 64.72, 64.73, 64.94, 64.82, 64.83, and 64.84), located on the southeast side of the mound, was excavated as part of the broader effort to understand Alalakh beyond its Royal Precinct. This specific location was chosen based on the presence of burnt bricks and MBA pottery and because of its position on a substantial rise, placing it well-above the surrounding area and marking it as a potentially important locale. Thus far, six phases of occupation have been recovered in this area, though only five can be addressed with any certainty due to significant disturbance of Phase 6 by burial activity. This area will be discussed in greater detail below, but the general character of Phases 5-1 may be summarized as follows: Phases 5, 4, and the earlier sub-phase of 3 represent episodes of substantial craft-production. During Phase 2, the Southern Fortress was constructed, contemporaneous with the Northern Fortress of the Royal Precinct, with some indication of continued craft activity in an adjacent area. Phase 1, largely destroyed by modern agriculture, seems to have been some sort of domestic context.(Akar, 2019, pp. 48–49).

| Yener Phasing | Woolley Phasing | Area 4 Local Phase | Area 1 South Local Phase | Area 1 North Local Phase |
|---|---|---|---|---|
| Period 0 | Possible Level Oa | - | - | 0 |
| Period 1 | Private Houses Ia-b | 1 – Squares: 64.72, 73, 82, 83, 84, 94 | 1 – Squares: 42.29, 43.54 | - |
| Period 2 | Fortress II | 2a-b Squares: 64.72, 73, 82, 83, 84, 94 | 2 – Squares: 42.29, 43.54 | 1 – Squares: 32.52, 53, 54, 62, 63, 64 |
| Period 3 | Fortress III and Castle Re-Use | 3a-b Squares: 64.72, 82 | 3, 4a-b-c Square 43.54 | 2a-b-c Square 32.54 |
| Period 4 | Palace/Castle IV | | | 2d Square 32.54 |

Table 3-1: Phasing synchronization between Woolley and new excavation areas. Table 1.1 from Yener et al. 2019, pp. 3.

At this stage, we are now in a position to propose a concordance between the phasing of the Area 1 and 4 excavations on the one hand, and those of Woolley on the other (Table 3-1).

Level IV can be associated with Period 4, which is not terribly controversial. Where problems began to arise in the Woolley sequence was after the destruction of the Level IV Palace/Castle complex. Here, he was at a loss to explain what had taken place, naming the subsequent occupation 'post-IV,' which included reuse of the ruins of the Level IV Castle. Adding further to the confusion, Woolley also struggled to disentangle the remains of the 'post-IV' structure from that of the succeeding Northern Fortress (his Level III/II Fortress). Work in 32.54 went a long way towards resolving this issue, showing that the castle reuse phase contained three successive re-floorings and, further, showing that Woolley had mistaken the final phase of the castle reuse for the first phase of the Northern Fortress. Thus, Woolley's post-IV/castle reuse, and Fortress III fit within Atchana Period 3, linked to the final years of Mitannian rule and the initial stages of the Hittite occupation, probably under Šuppiluliuma I. The Northern Fortress, now confirmed to be a single-phase structure, occupies Period 2, contemporary with Level II, representing the high point of the Hittite occupation, though there remains some debate about precisely who built it (Akar, 2019, pp. 26–33; Yener et al., 2019b, p. 338). Period 1 is then contemporary with Level Ia-b, while we have no reference to Level Ic. As can be seen from the preceding discussion, while Woolley was broadly correct on many points, the efforts of the new excavations have provided much-improved resolution, facilitating a more accurate chronology for the various phases.

In the present study, contexts from squares in Area 1 North (32.53), Area 1 South (42.10 and 42.29), and Area 4 (64.72, 64.73, 64.94, and 64.82) were selected for sampling with two aims in mind. The first was that I should be able to draw samples from stratigraphically secure contexts spanning Periods 5-2[7], while the second was that the samples provided should be as representative of the metallurgical assemblage at Tell Atchana as possible. Unfortunately, it was not always possible to meet these criteria with the stringency that I might have preferred, but the overall result is satisfying.

The contexts from 32.53, while generally stratigraphically secure, are somewhat ambiguous in terms of their production-related assemblages. In the course of excavation, several pyrotechnic installations[8] (Figure 3-4) were recovered, along with a large "crucible," though we are not in a position to attribute these unequivocally to metallurgical activity. Finds of small quantities of matte and slag do lend some support to the notion that these features may have served a limited metallurgical function. What is arguably more important for the 32.53 contexts is the larger proportion of finished objects comprising a wider variety of object types when compared to other areas of the site. This more varied

Figure 3-4: Broken pyrotechnical installation fragments in 32.53 Phase 2d. Photo Credit: Murat Akar. © 2020 Alalakh Archives

[7] This range encompasses the entirety of the Late Bronze Age into the terminal phase of the Middle Bronze II.
[8] As a general note, I use the term pyrotechnic feature/installation to denote any feature used to control and work with fire. This applies equally to the ubiquitous *tandır* ovens as well as metallurgical furnaces, in part because it is not always possible to establish a clear difference between the two as discussed in chapter 8.

artefactual assemblage, combined with this square's location in the Royal Precinct, make this a useful collection for comparing differential alloy use across object types and social contexts.

The Area 1 South contexts represent a rather interesting combination of settings to include in this study. Square 42.10 was originally meant to aid in the re-evaluation of the stratigraphy of Woolley's temple sounding. Over the course of excavation, several phases of architecture reminiscent of Woolley's "Private Houses" have been uncovered, and within these, there have been several phases of apparent metallurgical activity, interspersed with periods of a rather more domestic character. As such, this square provides an opportunity for evaluating potential workshop space within the Royal Precinct, as well as assemblages of elite finished products. Meanwhile, 42.29 was situated to the south of 42.10 with the goal of examining the interface between the Royal Precinct and the lower portion of the mound. Excavation here yielded essentially no intact architecture, except for a possible kiln along its southern baulk, instead being occupied by a large dump comprised of a variety of high value ceramic imports, elephant bones, and metallurgical debris. While this is not the most secure context, a small number of opportunistic samples were drawn from here for comparative purposes.

The contexts from Area 4 are the strongest in terms of stratigraphy and quality of finds. While there are a few minor questions regarding the precise associations of some walls, resulting from what I interpret as piecemeal modifications of the structure,[9] the overall phasing of this area and its links to the site-wide periodization are secure. Further, thanks to the wide horizontal exposures in this area, its identification as a workshop compound is well-supported, yielding a wide variety of production-related debris and finished objects.

[9] This is a problem Woolley also notes in his section on the "Private Houses" on the north end of the mound (Woolley, 1955, pp. 172–173).

Contexts from Areas 2 and 3, while they may have been potentially informative, given that both do seem to have housed workshops, were excluded from this study. The reasons for this are threefold. In the case of Area 2, the exposures were too shallow to provide a long-lived artefactual sequence, covering only two phases. While Area 3 does provide a sequence all the way down to the MBA city wall, the exposures are too small to provide a clear picture of localized activities. Furthermore, in both cases the assemblages of metallurgical debris were too limited[10] to justify their inclusion in this dataset and suggest that these workshop contexts were dedicated to other activities. As a final issue, there is the fact that we have not yet fully integrated these contexts into our site-wide periodization, which will be presented in upcoming Alalakh volumes 3 and 4.

The following discussion largely follows the conventions of the primary volumes of the Alalakh publications, presenting contextual data in a nested fashion, progressing from the largest area under discussion down to individual loci. Because a fair amount of this information has already been reported in Alalakh, Volume 2 (Yener et al., 2019a) or will appear in Volume 3, only those contexts which are directly relevant to the samples under consideration are discussed here. As such, I have opted not to use the compiled context format seen in the Alalakh excavation volumes, instead presenting individual loci and the relevant excavation lots. As the most recent seasons of the excavation are published, this will allow for simplified integration of the data presented in this dissertation with the official excavation publications. As a final

[10] Areas 2 and 3 combined produced only 149 metal objects and 18 slags, as opposed to 683 metals and 90 slags from Area 4. The totals for only those Area 1 contexts from which I drew samples are 239 metals and 64 slags. Furthermore, many of the unique AT numbers from Area 4 that refer to slags cover several fragments – AT4109, for example, refers to a 5kg collection of slag. The precise ratios between slag and metal may be slightly different, because items labelled slag by the field team are sometimes amorphous metals and vice versa and I have not had a chance to go back and reclassify the entire assemblage.

comment, the Context Keys provided with each context are formatted as Grid_Square_Locus_Lot. This is meant to provide the specific information listed above, while also serving as the identifier for the appropriate context in the database of finds associated with this dissertation project.

## 3.3 Contexts

### *3.3.1 Area 1 North*

As mentioned above, the excavations in Area 1 North constitute the heart of the effort to re-evaluate and correct the stratigraphic interpretation of the site.[11] Covering approximately 50,000 m², this area is the highest point on the mound and was the portion most thoroughly excavated by Woolley, containing several phases of palace and administrative complexes as well as temples.

The block of six squares (32.52, 32.53, 32.54, 32.62, 32.63, and 32.64) that comprised the primary investigative unit for the LBII in Area 1 North was situated extending westward from the southwest corner of Woolley's excavation cut. Since excavations began in 2003, two phases of architecture have been identified, comprising occupation from Periods 4-2. In the following discussion, information related to Square 32.54 and Phases 2b-c has been derived from Akar (2019, pp. 16–26), while a complete assessment of Phase 2d in this block will be provided in a later publication. As such, my discussion here will be limited to giving the general contours of the archaeological remains in 32.53 for the relevant phases.

[11] Aside from Woolley's original publication of the Atchana stratigraphy, Amir Fink (2010) also attempted a reevaluation of the site's phasing. This latter attempt, having been made based on photographs and highly preliminary excavation data, is of limited value. For the most up-to-date commentary on this topic see; (Yener et al., 2019a).

3.3.1.1 Local Phase 2: Within Area 1 North, Local Phase 2 can be divided into four sub-phases (a-d), represented in the construction and remodeling history of Building 2006-4. The earliest of these, 2d, has been established as contemporary with the occupation period of the Level IV Palace based on architectural links with the Level V-IV Serai Gate (Woolley, 1955, p. 115) via Wall L68 in Square 32.54 (L75 in 32.53 – Wall L75 in the remainder of the text) (Akar, 2012, p. 131). This substantial wall (1.7m thick and preserved to a height of 2.5m from the floor of 2d) continued in use through sub-phases 2c-a, with the Phase 1 Northern Fortress resting directly on top of its remains. In addition to Wall L75, we can now add new data from the 2017 field season where the excavation of a burial (L136) wedged into a drainage channel[12] provided a traceable ground-level link running through 32.54 and into the Serai Gate.

Because the re-buildings of 2006-4 all utilize Wall L75 as part of their structure, Local Phases 2c-a, despite belonging to a different Period (3) than 2d, are considered part of the same architectural unit. Over the course of its lifespan, this structure underwent several substantial modifications comprising approximately 3m of deposition.

*Building 2006-4:* This substantial structure, which through the 2006-10 field cycle had only been revealed in Square 32.54, has since been explored in greater detail, confirming initial judgements about the nature of the structure and its stratigraphic relationships. In addition to the continued and substantial presence of Wall L75, Burial L136 has provided evidence of a drainage feature linking the western extent of the new exposures to adjacent

[12] There remains some debate on the precise nature of this channel, whether it is merely a drainage ditch, or if it was related to possible textile dyeing activities (Tara Ingman, Personal Communication).

contexts and into the *Serai Gate* area, providing further support for the linkage of Local Phase 2d (Period 4) with the Level IV Palace and Castle.

> Local Phase 2d (Figure 3-5): Remains in this phase of 2006-4 are quite varied, with indications of both textile-related activity and a varied metal assemblage. Despite a lack of metalworking debris, the rationale for drawing samples from these contexts was the interesting range of finished goods present, including a small ingot (AT24079), an arrowhead (AT24621), and a small, probably decorative, tack (AT24677). In terms of overall impression, the structure appears to have been a service wing of the palace that clearly suffered an episode of substantial burning, likely to be associated with the destruction of the Level IV Palace and Castle. Thus far, five rooms connected by various corridors have been unearthed with a small entry corridor linking this part of the complex to the *Serai Gate*.

*Locus 105 (L105), Context Key 32_53_105_404:* This context was an intact *in situ* vessel situated above Room L130, but below the 2c-d transitional deposits.

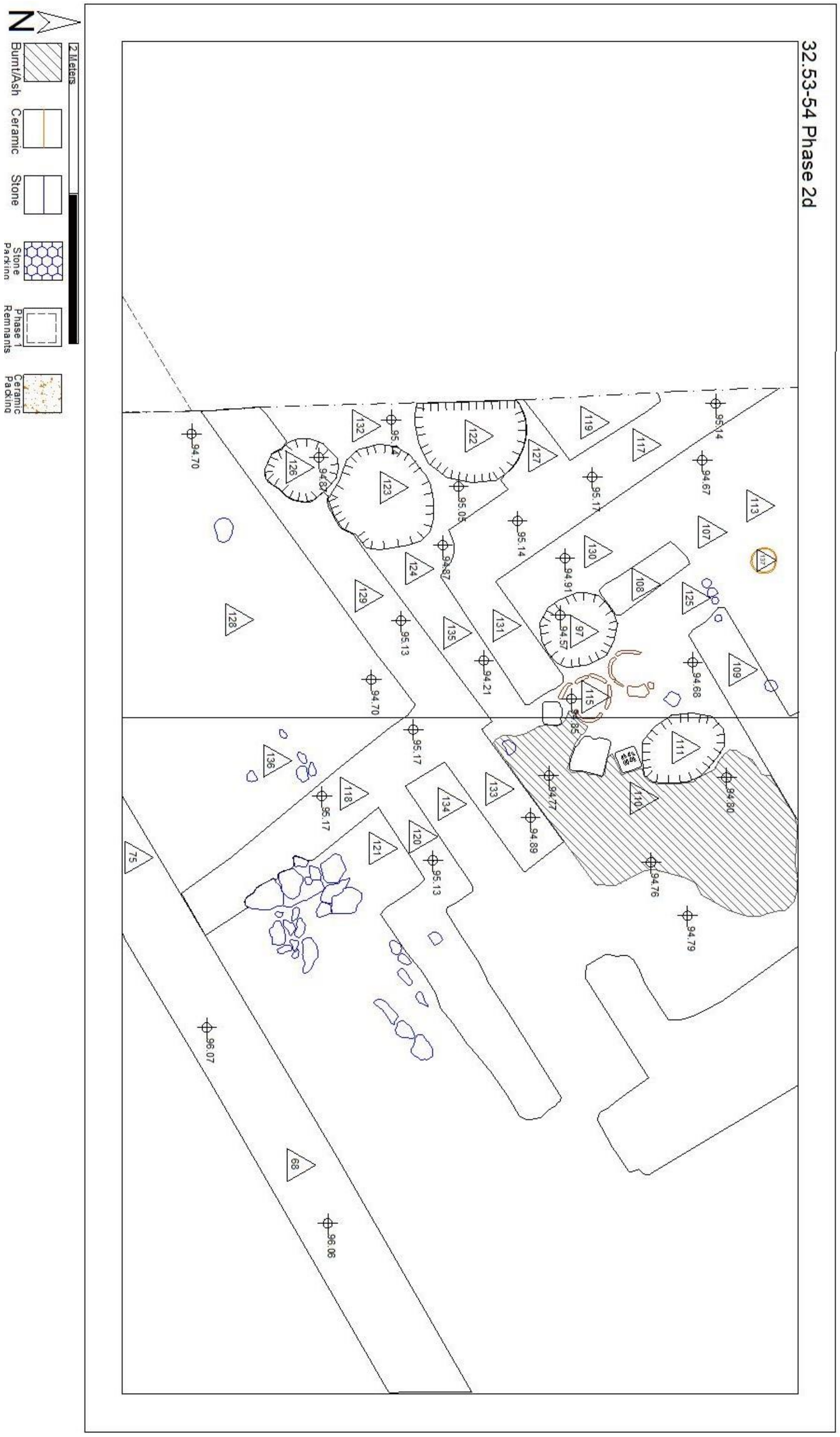



Figure 3-5: Top Plan, 32.53-54 Phase 2d. © 2020 Alalakh Archives

This, in combination with finds of burnt timbers and large *in situ* broken basins, has led to the conclusion that a second story collapsed during the destruction phase, with L105 being one of two vessels to have descended from the second story. Inside of this vessel, a small (4.9x0.8x0.9cm, 31g) bar ingot (AT24079) was located. Between its form, weight - equaling roughly 3.5 shekels (Ugarit shekel (Stieglitz, 1979)) - and indisputable context, this object represented an ideal candidate for sampling as an example of metals circulating as exchange media.

*Locus 110 (L110), Context Key 32_53_110_426:* This room (exposed 6m SW-NE x 4m NW-SE), which represents a continuation of Locus 78 from Square 32.54, is the first room entered upon coming into the building. The entryway is marked by a cement floor in the northeast extent of the room, at which point there is a step down into the western half. The fill of this room was generally quite sterile and heavily burnt, forming a deposit nearly 1m in depth (95.37-94.31 masl). Locus 115, located against the western wall of L110, is a fairly large portable shaft furnace of moveable hearth akin to examples recovered from Area 3 (Yener and Yazıcıoğlu, 2010, p. 44). Located immediately west of this hearth was a large crucible-like vessel with signs of vitrification on its internal surfaces, which could have been placed underneath the hearth to catch something. If this installation did serve any metallurgical purpose, it would probably be linked to secondary working of metals involving processes like forging and annealing, given the general paucity of slags and other equipment related to casting. Alternatively, an installation for combining lumps of copper into larger ingots also seems like a possibility, though evidence for this is, once again, scarce. A partial arrowhead (AT24621) was recovered in L110. Beyond this, *voussoir* (cf. Woolley, 1955b, p. 26) bricks, obsidian, and beads comprised the assemblage of this room.

*Locus 113 (L113), Context Key 32_53_113_440:* Located immediately north of L110, L113 is a partial room forming part of the same complex. Only the southern corner of the room was excavated, the remainder still being within the north baulk. The fill of the room was, like the other rooms in this structure, comprised of burnt mudbrick collapse. A significant difference, however, lies in the fact that underneath the collapsed fill, there was little indication of burning. The lack of a coherent floor level in this context suggests that this room probably saw relatively limited use. Sample AT24677, a small tack, was drawn from here. In addition, L113 also yielded glass, an anthropomorphic figurine, and a stone vessel.

<u>Local Phase 2d-2c Transition (Figure 3-6):</u> This transitional phase is comprised of a combination of collapse from the second story of 2006-4 and levelling fill. Overall, the material in these contexts tends to be heavily burnt, including vitrified mudbricks and collapsed plaster fragments. This phase is most likely comprised of two more or less distinct depositional events, the first being related to the collapse of the 2d structure during its destruction, and the second being an intervening period prior to the construction of Phase 2c. The top of the former, indicating the vertical extent of the sealed collapse deposit, should probably lie somewhere around 95.65 masl as demarcated by the top of L105, while the bottom would be approximately 95.45 masl as suggested by the appearance of the large timber associated with Locus 112, which probably supported the second

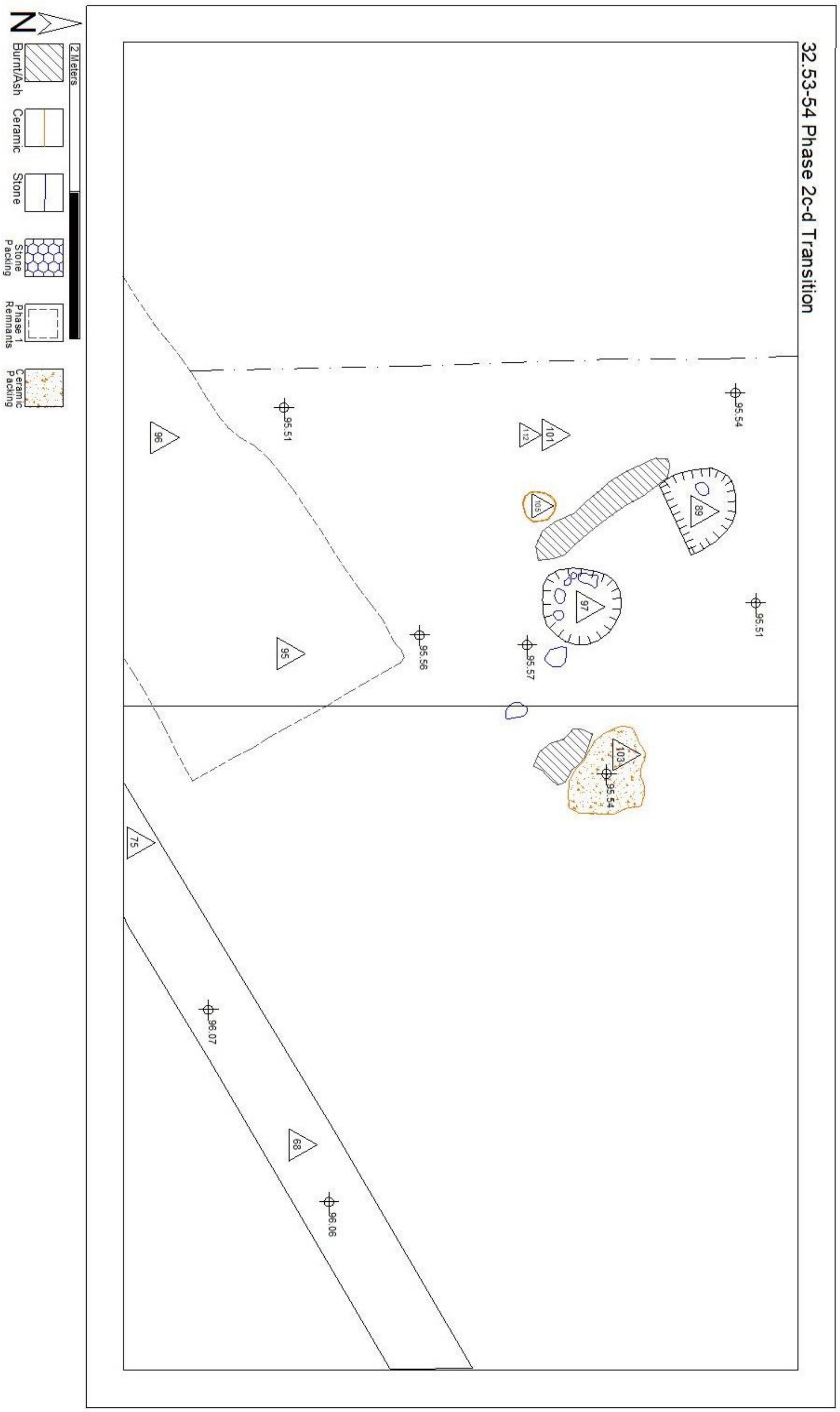



Figure 3-6: Top Plan, 32.53-54 Phase 2c-d Transition. © 2020 Alalakh Archives

floor. Between 95.65 and 95.73 masl, the latter elevation denoting the lowest wall foundation associated with Phase 2c, this phase should be characterized as a brief period where the area was exposed to the elements and possibly constituted a limited outdoor activity area, as indicated by burnt patches and water-eroded sherds. After this brief period, the presence of archaic sherds suggests that a levelling fill was applied and the Phase 2c building erected. Despite the obvious problems with these contexts as destruction and fill layers, as an *in-situ* vessel, L105 can be reasonably taken to mark an essentially contextually trustworthy layer linked to the collapse of 2006-4's second story.

*Locus 101 (L101), Context Keys 32_53_101_380, 384, and 386:* L101 constituted the general transitional layer between 2d-c, incorporating both depositional events discussed above. Locus 104, the successor to L101 and extending between approximately 95.46 – 95.36 masl, contains material trapped below the fill resulting from the second story collapse of the building. L101 itself was characterized by heavily burnt patches and relatively sterile fill. The lots from which samples were taken (380, 384, and 386) all occurred within a relatively narrow span (95.56 – 95.48 masl) across the surface of L101 near its lowest extent. Within this material a sizeable fragment of matte (AT23799), a drill point (AT23902), an amorphous fragment (AT23953), and a hockey-stick shaped kohl stick (AT23960) were recovered and sampled.

<u>Local Phase 2c (Figure 3-7):</u> Phase 2c in 32.53 is characterized by two sub-phases, labelled "early" and "late" in the original excavation literature, the former being characterized by mud-brick construction, while the latter saw those walls


Figure 3-7: Top Plan, 32.53-54 Phase 2c Early/Late. © 2020 Alalakh Archives

overlain by stone foundations, but constituting essentially the same structure. Associated with Period 3, most of the exposed area attributable to this phase consists of outdoor space (a possible continuation of activities from the latter days of the 2d-c transition period) occupying the western extent of the exposure, while the fragmentary remains of two rooms occupy the east. Ashy deposits covering the floors of these rooms may indicate the former presence of pyrotechnical installations or a limited burning event in the occupational period of this phase (Akar, 2019, p. 20).

*Locus 90 (L90), Context Key 32_53_90_367:* L90 belongs to the early (95.85 – 95.70 masl) sub-phase of Phase 2c and constitutes the outdoor section of 2006-4 in this phase. Overall, trashy deposits with mixed, fragmented material and very compact soil characterized the floor level, yielding a variety of beads, metal fragments, and chipped stone material. Because of the exposed nature of this deposit, only a single sample was collected, being taken from a heavy sheet fragment (AT23729).

<u>Local Phase 2b (Figure 3-8):</u> While the portion of building 2006-4 represented in the eastern portion of 32.53 (i.e. that part which had originally been 32.54) largely represented a continuation of the architecture seen in Phase 2c, with the exception of having more substantial stone masonry foundations, the western portion of the square shows a substantial reorientation. Principally, what had been an open outdoor space was enclosed on three sides by walls, creating a long space extending into the western baulk. Two of the three walls were characterized by well-built masonry consistent with that seen in the eastern part of the square, while the southern wall (Locus 53) was rather standard mudbrick. This wall gives the possible impression of a later partition wall, given its disconnection from the stub of stone-wall Locus 63 (Locus 104 in 32.54). The northern wall (Loci 54 and

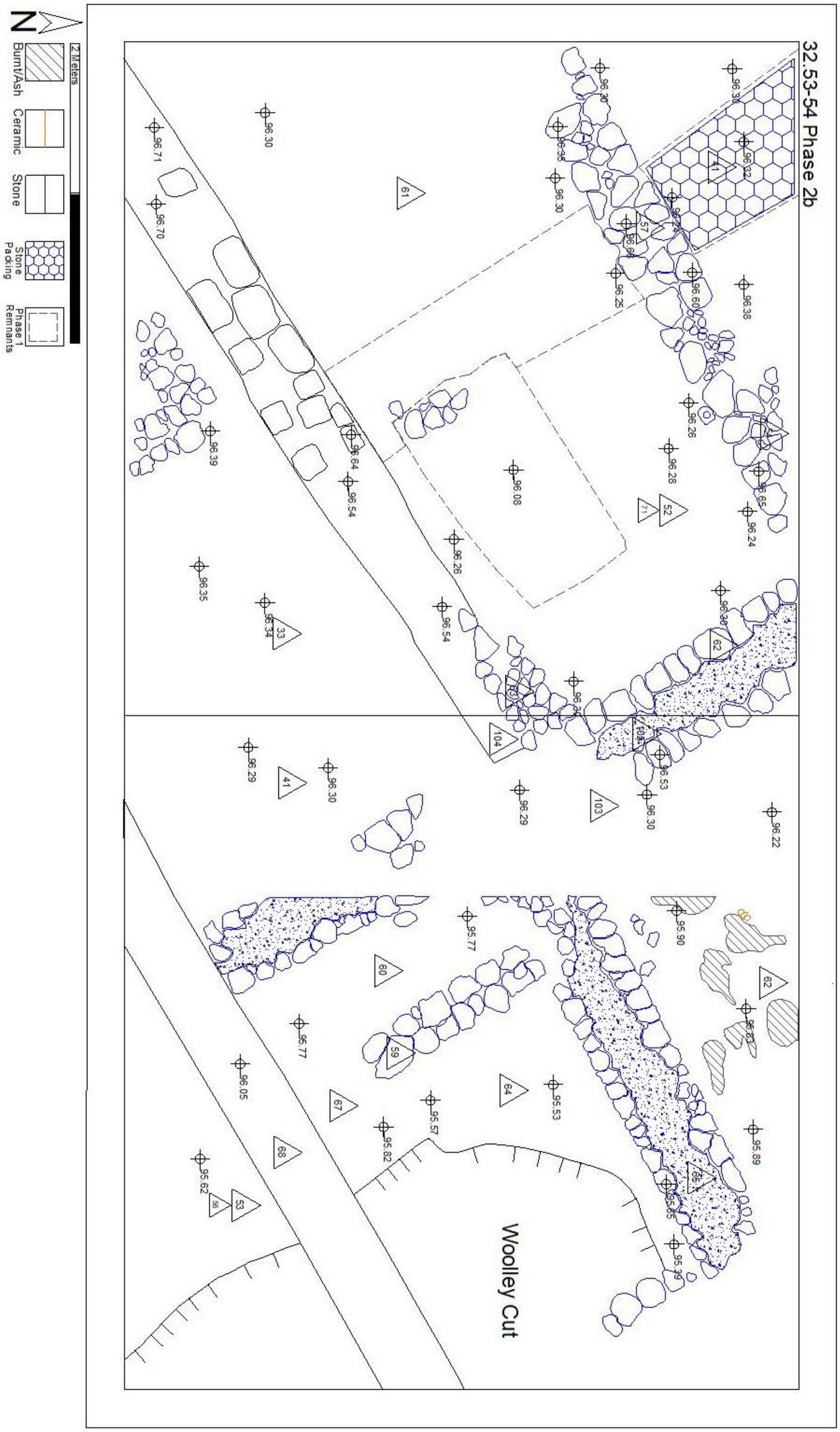



Figure 3-8: Top Plan, 32.53-54 Phase 2b. © 2020 Alalakh Archives

57) hosted a doorway that led to another room largely covered by the north baulk. The central space is bisected by a clearly delimited disturbance from the laying of the Northern Fortress foundations.

*Locus 61 (L61), Context Keys 32_53_61_204, 205, and 214:* L61 (96.70 – 96.19 masl) represents the half of the large central space lying on the southwest side of the Phase 1 foundation square. In general, substantial burning, large quantities of chipped stone debitage, and a smaller amount of metal characterize this context. Given these characteristics, it is rather tempting to label this as small courtyard for the surrounding structure. Three samples of amorphous metal (AT19447, AT19901, and AT19926) were taken from L61. Given their size and the quantities of charcoal embedded in them, two points seem likely. First, rather than being casting spill, these are unagglomerated fragments of metal from a primary smelting operation. Second, despite the lack of obvious pyrotechnical features and other equipment (i.e. crucibles – this paucity is a typical feature of workshop spaces at Atchana), the amount of burning in evidence in L61 may suggest that it is a locale where such unagglomerated pieces could have been melted down into larger masses.

*Locus 71 (L71), Context Key 32_53_71_251:* L71 (96.28 – 96.03) represents the portion of the central space to the northeast of the Phase 1 foundation square. Because this locus most probably represents fill between Phases 2b and 2c, only one sample (AT20638), probably part of a small carving tool, was drawn from this context.

### *3.3.2 Area 1 South*

Work in Area 1 South began with the opening of trenches 43.54 and 42.29 in 2007 and 2009, respectively. The former was excavated for three seasons (2007-2009), while the latter was excavated for two (2009, 2012). Situated 30-40m south of Woolley's main excavation cut, the main goal of excavation in these trenches was to elucidate the relationship between the Royal Precinct and the lower part of the tell. Both trenches yielded four phases from 1a-4c, though they differed substantially in character during their Phase 4 occupations. Notably, while this phase in 43.54[13] is characterized by part of a substantial, well-accounted building yielding a variety of votive ceramics, 42.29 appears as an elite dump. In 2012, a further square, 42.10, was opened approximately 10m south of Woolley's temple sounding with the hope of shedding some light on the complex stratigraphy of that area and linking it to the rest of the excavation sequence. This square has been excavated in all seasons (up to 2019, at least) since that point, yielding seven phases of architecture comparable with Woolley's private houses.

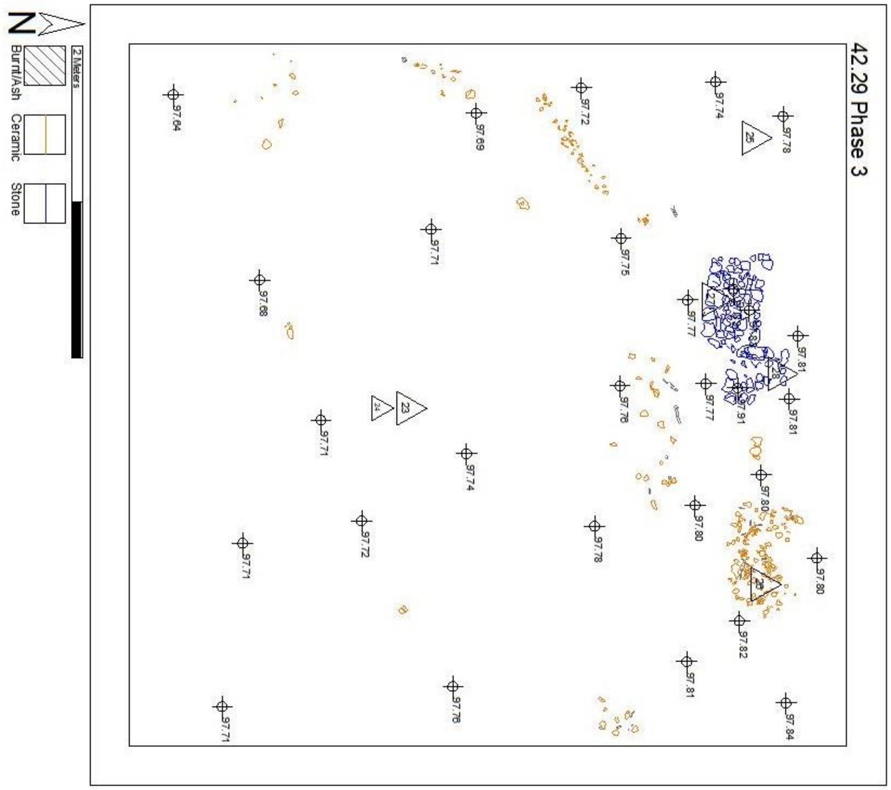
Samples were selected from contexts in trenches 42.29 and 42.10 assigned to Period 3. In the case of 42.29, though the corpus of metallurgical remains was quite substantial, the fact that most of these objects derived from a midden dissuaded me from taking more than a couple notable samples. For 42.10 most of the samples concerned were selected from Local Phase 4 contexts, allowing a general chronological association with the seal impression of Tudḫaliya and Ašnuḫepa at the turn of the $14^{th}$ – $13^{th}$ centuries BC (Yener et al., 2014). Because the phases of these two trenches do not directly correspond, each will be dealt with individually.

[13] A single sample – AT6393 – was included from 43.54. It had been taken as part of an earlier set of samples unrelated to this project, however, when it was revealed that it was a speiss sample, it was included opportunistically as a worthwhile exemplar of the material.

3.3.2.1 Square 42.29: Over two years of excavation, square 42.29 has yielded four occupation levels. The first two, discussed in Alalakh, vol. 2 (Akar, 2019, pp. 43–48), date roughly from the Hittite takeover of the city around 1330 until its substantial decline around 1200 BC. Phases 3 and 4 are then to be associated with Period 3, covering the span from the destruction of the Level IV Palace (currently estimated at 1400 BC) until the city's annexation by Šuppiluliuma I. Given the high-status associations of the assemblage, its proximity to 42.10, and the consistent – even if low intensity – presence of metallurgical debris in 42.10, drawing samples from these contexts is warranted. Considering the contextual concerns presented by dump contexts, however, only two samples were taken, one deriving from Phase 3 and the other from Phase 4.

3.3.2.1.1 Local Phase 4: This phase, comprised of three sub-phases (a-c), constitutes a large open area devoid of architectural remains except for a kiln-like installation along the southern baulk. Otherwise, a large midden dominates the northern part of the square.

Local Phase 4c (Figure 3-9): This was the last phase excavated in 42.29. As with later phases, no architectural features are visible, and the primary feature of the square is a dumping area in the north. The ceramic assemblage is dominated by Cypriot imports, with an emphasis on Monochrome, White Slip I, White Slip II early, and Base Ring I wares. On the whole, this collection suggests that this phase should be attributed to Period 2 or 3, while the relative quantities of Base Ring I, Monochrome, and White Slip II would tentatively lean toward a Period 3 date (Kozal, 2019, pp. 270–272). Otherwise,



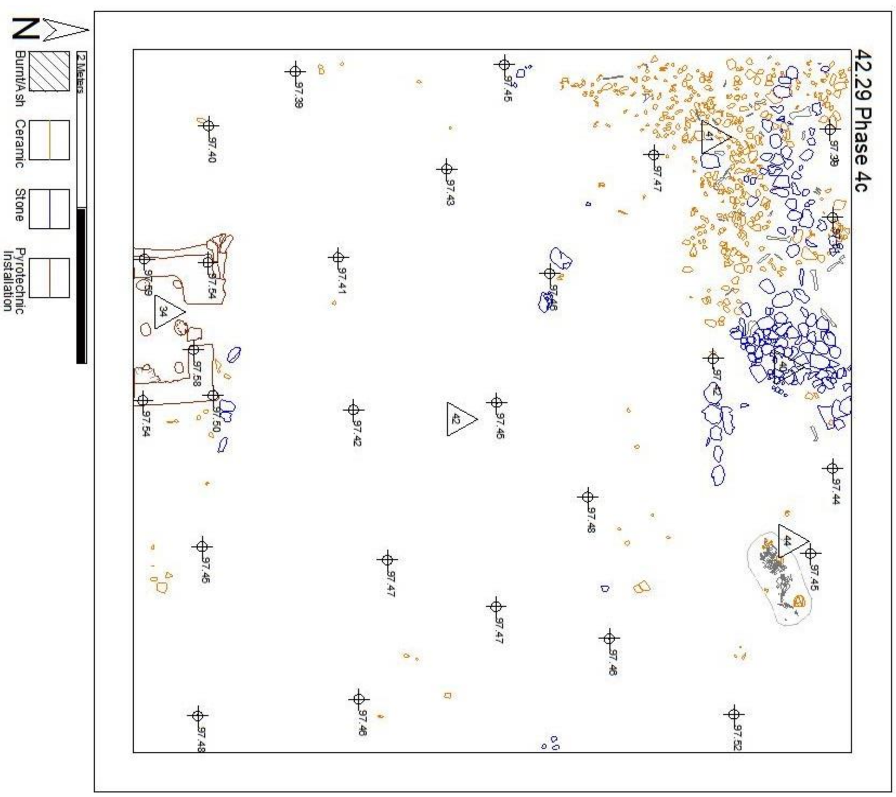




Figure 3-9: Top Plan, 42.29 Phases 3 and 4c. © 2020 Alalakh Archives

this phase hosts very large quantities of metal fragments, slag, partial stone vessels, and stone tools.

*Locus 41 (L41), Context Key 42_29_41_239:* L41 represents the continuation of the midden in Phase 4c. By the end of the 2012 season, it was apparent that this feature continued deeper. Due to the high percentage of valuable imported ceramics, as well as intact bones, including those of elephants, we concluded that this dumping area could be directly attributed to activities in the Royal Precinct. Given the substantial numbers of larger sherds and intact bones, identification of this locus as a street or drainage canal also seems unlikely. Beyond the ceramics and animal bones, a surprising quantity of metallurgical debris came from this context. Given this contextual association with the palace, substantial amount of metallurgical material, and the presence of a considerable pyrotechnic feature, taking a slag sample from this context despite the obvious concerns seemed warranted (AT19330).

3.3.2.1.2 Local Phase 3: Phase 3 (Figure 3-9) represents the last phase in which this area is used as a dumping ground, being followed by the construction of a domestic structure after about 25cm of accumulation deposit. There are the apparent remains of a very short (approx. 1m) section of a stone wall. However, they do not articulate with any of the Phase 2 or 1 architecture and give no indication of being part of a more substantial structure. Otherwise, this phase is characterized by essentially the same material as the preceding Phase 4.
*Locus 23 (L23), Context Key 42_29_23_148:* L23 is actually identified as the accumulation layer between Phases 2 and 3, however, Lot 148 is more

accurately assigned to Phase 3 based on its elevation (97.73 masl). This places it essentially in line with the ancient ground level of Phase 3 between 97.77 and 97.71 masl. Finds of metal fragments, large quantities of animal bone, and a Mitannian cylinder seal suggest that this represents the terminus of the high-status dump in this area. Nevertheless, because of the questionable context, only one sample (AT16577) was taken from here.

3.3.2.2 Square 42.10: This square has been particularly intriguing since excavations there were initiated in 2012. The first occupation level, dating to the Iron Age, was rather ephemeral but represented a definite continuation of occupation after the main abandonment event at the site. In the preceding phases 3a and 3b, transitional between the LBII and Iron Age, evidence was found for metallurgical activity including a small pyrotechnic installation as well as a fragment of speiss (Johnson, 2020). The earlier Phase 3b, which yielded the speiss, has now been dated to approximately 1250 BC (Mia Montesanto, Personal Communication 2019). Below this, we have identified five occupation levels, which, though their precise character varies, tend to give the impression of being a service wing of the temple, often showing facilities for food preparation and other activity accompanied by a variety of metal objects and a lesser quantity of metal production debris. Beyond mundane domestic activity, this square has also yielded offering tables, *in situ* figurines, an elephant scapula, and two pits containing sacrificed cattle, one of which likely formed the foundation deposit for the Phase 4 building.[14] In the earlier phases, direct evidence for metalworking appeared in the form of several small jewelry molds

[14] These features of the square will be dealt with in a later publication.

and one large multi-faceted mold recovered during the 2018 season. For our purposes, however, only phase 4a and 4b contexts were available for sampling.

3.3.2.2.1 Local Phase 4: The Phase 4 structure represents the last identifiable architectural feature in this square that can be attributed definitively to the LBII. This designation has been made on the basis of LHIIIA2 and B ceramics that allow for a tentative dating to the second half of the 14th century BC, which is then in agreement with the Tudhaliya sealing (Montesanto, 2017; Yener et al., 2014). Over the course of Phase 4, the building remains largely the same, with a single modification taking place between 4a and 4b to restrict the outdoor courtyard space.

Local Phase 4b (Figure 3-10): In Phase 4b the structure consists of at least 4 rooms adjoined to a courtyard space to the east via a large doorway with a threshold of large stones. Overall, the contexts within this phase of the structure tended to be clean, yielding a limited range of material. Interior spaces showed some localized burning, probably related to domestic or craft activity. Meanwhile, the exterior space to the east hosted two large pyrotechnic features with a similar variety of metal implements, slag, shell, and shell beads to that seen indoors.

*Locus 42 (L42), Context Keys 42_10_42_188 and 203:* L42 represents the courtyard area external to the domestic structure that is later bisected to form L39 in Phase 4a. A slag fragment (AT21470) and a shaft fragment (AT21536) were sampled from this context.

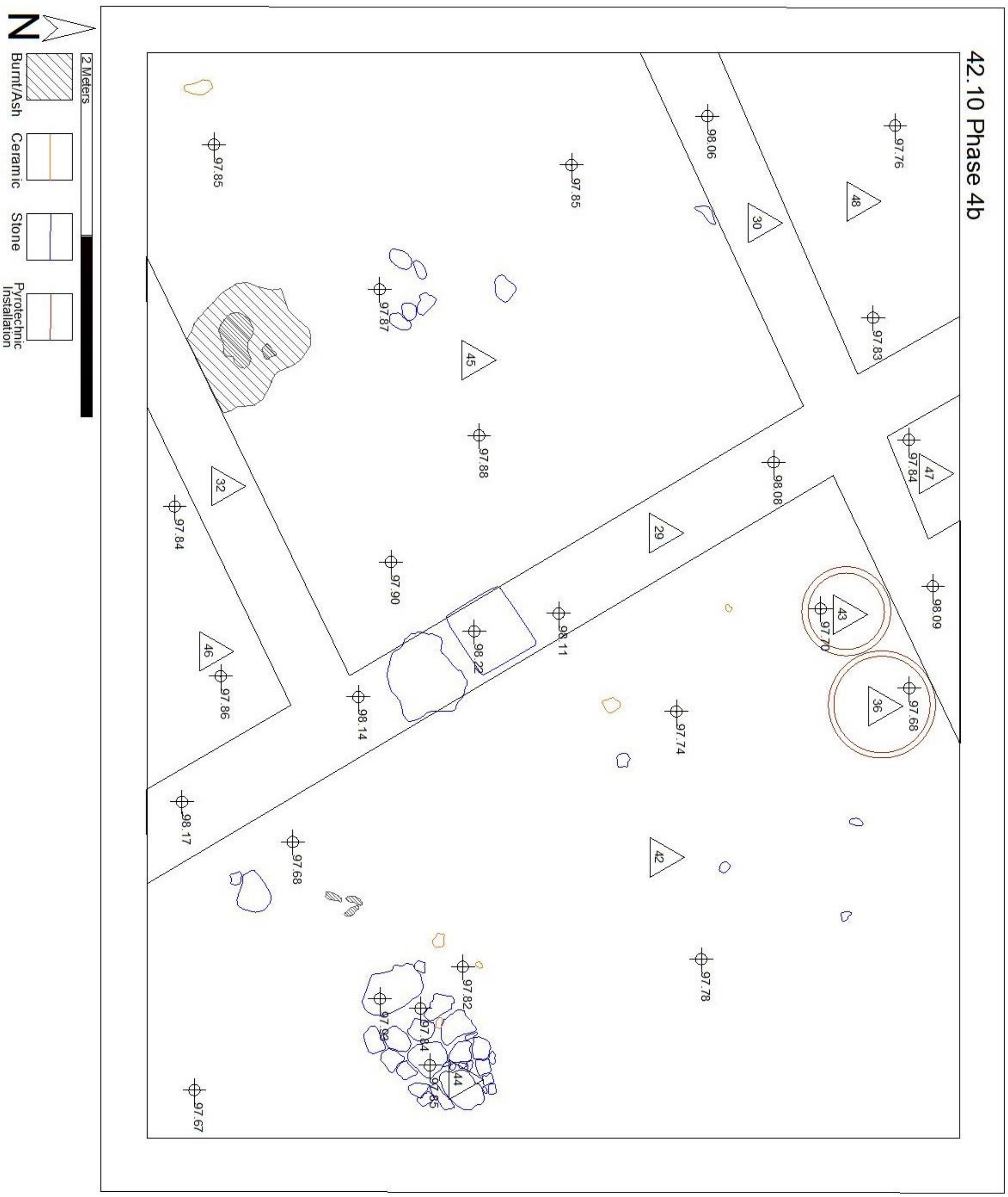



Figure 3-10: Top Plan, 42.10 Phase 4b. © 2020 Alalakh Archives

*Locus 45 (L45), Context Key 42_10_45_199:* Interior space of the structure with a central support for a column. Some areas of localized burning are visible on the floor, though there is no indication of pyrotechnic features. A hefty awl (AT21510) was sampled from this context.

Local Phase 4a (Figure 3-11): In Phase 4a the structure remains largely the same as in the preceding phase with the exception that the courtyard to the west was bisected by a wall, allowing for the installation of a (at least partial) roof. In this phase of the structure, two pyrotechnic features are present in separate rooms and the floors of the structure show substantial ashy deposits. The special nature of the buildings in this square appeared early on in excavation with this phase yielding, in addition to a miniature Hittite pitcher, a seal impression of Tudḫaliya and Ašnuḫepa.[15]

*Locus 27 (L27), Context Key 42_10_27_151:* L27 is a pyrotechnic feature located along Wall L32 and in Room L31 that yielded several fragments of metal. Of these, one fragment of copper-based sheet (AT20433) that has been folded over, seemingly to create a borer, was sampled.

*Locus 31 (L31), Context Keys 42_10_31_155 and 165:* This space constitutes the largest room in the Phase 4 structure. Interestingly, despite the presence of L27 as well as the suggestion of another hearth-like feature along the western baulk (Locus 26), this space actually appears to have been roofed over as indicated by the arrangement of stones at the center of the room that were likely a column support. The overall assemblage of the room is interesting and

[15] This is to be related to the orthostat recovered from the IB temple during the Woolley campaigns (Woolley, 1955, p. 86; Yener et al., 2014).

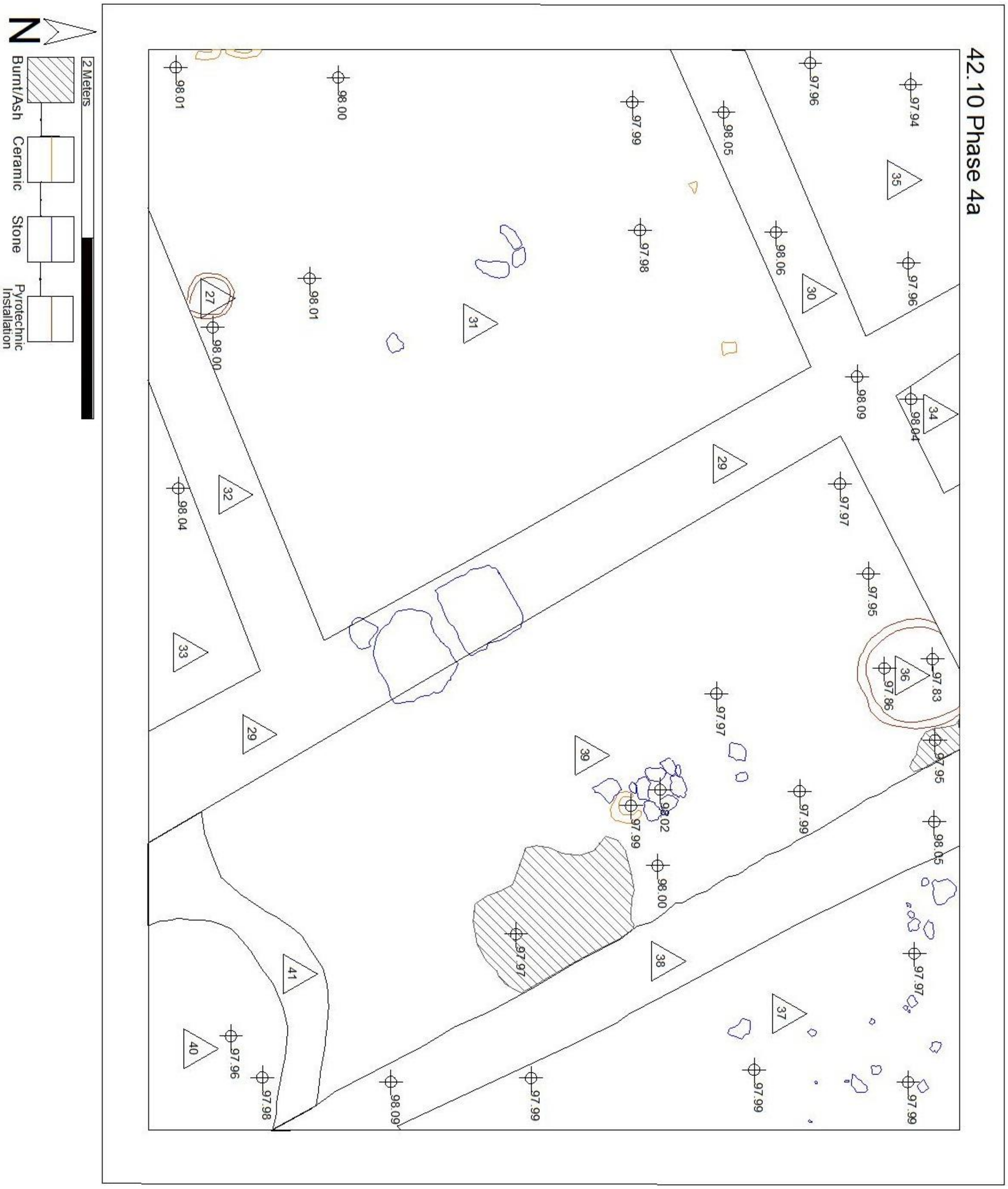



Figure 3-11: Top Plan, 42.10 Phase 4a. © 2020 Alalakh Archives

pyrotechnic features and other evidence of burning that would usually be taken to suggest cooking activity, the very low proportions of cookware (69 *sherds* out of a total of 908 collected from this locus, ~7.5%) would tend to downplay that perspective. This leaves us to consider the quantities of chipped stone, metal, hand stones, whet stones, and beads, which would be more indicative of low intensity craft activity. Two objects were selected for sampling from this context – the edge of a chisel blade (AT20450) and a shaft fragment (AT21204).

*Locus 39 (L39), Context Key 42_10_39_183:* L39 is a room adjoining L31 through a broad doorway floored with two large pavers. At the southern end of the room is a large, silo-like feature, while a sizeable pyrotechnic feature is located at the north end. The intervening floor surface is extremely ashy and somewhat more mixed. Given the presence of a similar column support to that seen in L31, it seems probable that this space was only partly roofed, in view of the nature of the floor deposit. Overall, the assemblage of L39 was less mixed than that of L31. Though it did yield a few metal fragments and beads, the quantities were generally lower, while stone hand tools and chipped stone debitage were non-existent. The presence of the  pyrotechnic feature and silo, along with parts of a basin, raise the question as to whether this space may have been related to beer production. In this connection, AT21454, a beer strainer, is significant and represents the only sample drawn from this context.

### *3.3.3 Area 4*

Work in Area 4 began in 2006 with the previously stated aim of investigating areas of the mound outside of the Royal Precinct. Over the course of nine seasons of excavation, we have been able to reveal remains spanning six phases of occupation with all but Phase 2 being either domestic or workshop related based on our current interpretations.

During the first season of excavation in Area 4, work took place in trenches 64.72 and 64.82, revealing the Southern Fortress (Building 2006-2). In 2007, the remaining Area 4 trenches (64.73, 83, 84, and 94) were opened with the intent of further investigating Building 2006-2. Subsequently, in 2008, excavation continued in 64.72 and 64.82 to begin examining the levels underlying the Southern Fortress, bringing to light Buildings 2006-3 and 2008-1. After a brief hiatus in activity in Area 4, in 2011 trenches 64.72 and 64.83 were excavated, revealing Phases 3b and 4 in the former, and extending our understanding of the Phase 3a architecture in the latter. In 2012, 64.73, 84, and 94 were all brought under excavation to gain a complete view of the Phase 3 architecture, which provided us with an extensive plan of Building 2008-1, though our exposure of the structure remains incomplete. In 2014, work was continued in 64.72, bringing to light Phase 5. In 2015, 64.72 and 73 were excavated, revealing Phase 6a in the former and Phase 4 in the latter. In 2016, 64.72 was excavated, revealing two additional sub-phases of Phase 6, and in 2017, 64.73 was excavated, expanding our Phase 5 exposure. In this most recent season (2019), continued work in 64.73 brought to light phase 5b, as well as a very limited exposure of Phase 6 material. Based on recent[16] analysis of the ceramic assemblage of pre-Phase 2 levels by Drs. Marina Pucci and Mariacarmela Montesanto in 2018 and 2019, Phases 2 and 3 may be attributed to the LBII, Phases 4 and 5a represent the LBI/II transition, Phase 5b dates covers the

[16] The results of this analysis will appear in Alalakh, Volume 3.

LBI, and Phase 6 includes the end of the MBII.[17] Within the site-wide periodization, Phase 2 corresponds to Period 2, Phases 3a and 3b fall within Period 3, while the remaining phases have yet to be attributed.

It is generally possible to outline a progression in activity from Phases 5a-2. Starting with Phase 5a, this is the first period where metallurgical activity occurs in Area 4, with the remains of the 5b structure being used as an impromptu workshop.[18] The ceramic assemblage for this phase shows a lesser degree of standardization than later phases, with a greater emphasis on smaller "individual serving" vessels. Phase 4, marking the transition from the LBI to LBII, displays a significant shift in ceramics, architecture, and production activity. The buildings in this phase tend to be better constructed, showing less indication of being improvised structures. Meanwhile, the ceramic assemblage of this phase displays greater standardization and a shift toward communal serving vessels. Finally, production activity during this phase appears to expand and diversify, showing peak density of metallurgical and glass-related production debris. Phase 3b marks the maturation of the trends seen in Phase 4. The architectural plan, while displaying some significant differences, does appear to derive from the earlier Phase 4 construction, while the density of metallurgical debris shows general continuity until Phase 3a, when it appears to decline significantly. Phase 2, the Southern Fortress covered in detail by Akar (2019, pp. 314–317), represents a complete shift in architecture and use following the takeover of the city by the Hittites. Nevertheless, a limited amount of production activity appears to persist to the east of the structure in an open courtyard space.

[17] Because no samples were taken from Phase 5b and 6 contexts, these levels are not considered here and will instead be presented in Alalakh, Volume 3.
[18] A similar pattern of using abandoned structures as workshop spaces can be noted in the Proto-Elamite levels of Arisman in Iran (Vatandoust et al., 2011).

3.3.3.1 Local Phase 5 (Squares 64.72 and 64.73): Phase 5 (Figure 3-12) is characterized by what appears to be two structures abutting onto one another in 64.72 and a relatively open work area with minimal architecture in phase 5a of 64.73. The area enclosed by walls L62 and L114 on the south baulk of 64.72 represents one of the structures, while the remaining walls comprise another structure built immediately adjacent to it with L115 being the connecting wall. Ultimately, the impression given by current evidence suggests largely open, partially roofed stalls and courtyard spaces with substantial indications of burning and relatively scant finds dominated by slag and small metal fragments.

In 64.73, loci 91 and 92 form a freestanding corner shielding locus 93. The space between loci 91/92 and 93 was filled with an extremely thick accumulation of white ash that extended across the floor surface to the north and west. Locus 93 itself, constructed of broken mudbricks in a rather *ad hoc* manner, hosted the fragmentary remains of two pyrotechnical installations on its northeast face, the back walls still being in the platform with a ring of burnt earth forming a circle in front of each. In the course of excavating Locus 78, large fragments of these installations were recovered from in front of the platform. Below these, we found large quantities of amorphous metal fragments and part of a clay mold (AT26104) was excavated from the southeast corner of the square.

*Locus 109 (L109), Context Key 64_72_109_487:* L109 represents an outdoor space with some general indications of burning in the southwest corner of the square enclosed by walls L62 and L66. This locus yielded several slags and a couple amorphous metal fragments, including sample AT20765.

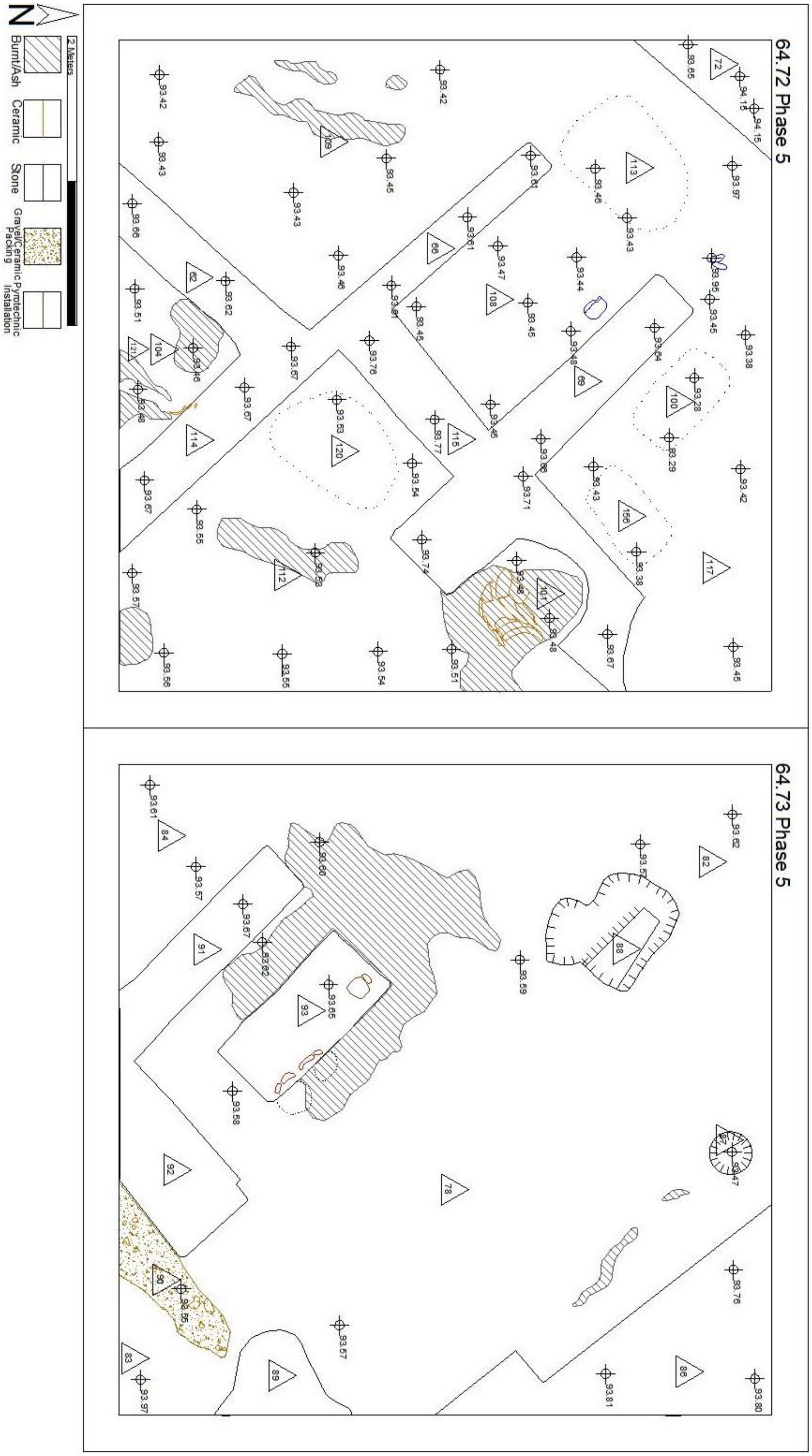



Figure 3-12: Top Plan, 64.72,73 Phase 5. © 2020 Alalakh Archives

*Locus 113 (L113), Context Key 64_72_109_487:* While L113 denotes a pit to the north of L109, lot 487, from which sample AT20717 was derived, should still constitute part of the floor surface of L108 based on continuity in soil patterning. That is, the pit was initially identified by cracking around its margin due to settling of its fill, rather than soil differentiation between the fill and surrounding surface. As such, I am comfortable in associating this context with L108 and its attending Phase 5.

*Locus 78 (L78), Context Keys 64_73_78_302 and 305:* L78 constitutes the central open area of 64.73, northeast of L93, and was maintained across Phases 4b and 5. Phase 5 deposits begin at approximately 93.76 masl after a layer of extraordinarily clean mudbrick fill, probably from the destruction of the Phase 5 walls, and continue to approximately 93.56 masl. Aside from a very dense concentration of metal globules, and the previously mentioned mold fragment, this area also yielded a substantial quantity of large chunks of heavily vitrified material, possibly related to a pyrotechnical installation. Samples taken from this context were amorphous lumps AT25628, AT25629, AT25637, and AT25650 and sheet fragment AT25644. Though listed as deriving from Locus 85, the phase 4b wall that ran above Locus 93, sheet fragment AT25687 can also be grouped with these finds, having derived from the floor level in front of Locus 93 during the removal of Locus 85.

3.3.3.2 Local Phase 4 (Squares 64.72 and 64.73): The extent to which the Area 4, Phase 4 architecture forms a contiguous whole is debatable due to the limited extent of our current exposure. However, insofar as the architecture of this phase presages developments in Phase 3, and considering their proximity, it is reasonable to posit that they are at least closely related.

In 64.72 we see the construction of a substantial structure with an apsidal feature in the north of the square (interior spaces composed of Loci 79 and 89) that is supposed to have housed a glass kiln or other pyrotechnical installation, as suggested by the sudden appearance of considerable quantities of glass slag, as well as glass objects and fragments in this area.[19] In the southern part of the square, we have another structure housing a large room (Locus 63) with extensive ashy deposits toward its southern edge that yielded significant amounts of slag and a lesser quantity of metal. Finally, Locus 75, along the western baulk, contained the outer edge of a small pyrotechnical installation surrounded by a halo of light gray ash that yielded slag, glass, and metal. Overall, indications of localized burning are abundant for this phase in 64.72, which, in combination with the general assemblage of finds, indicates a rise in production-related activity.

In 64.73 we were able to identify two distinct sub-phases for Phase 4 that share similar architectural contours.

> Local Phase 4b (Figure 3-13): In Phase 4b what had appeared as an open space in Phase 5, was enclosed on three sides and ceased to host identifiable pyrotechnical features. Nevertheless, there are still substantial and widespread deposits of ash, as well as a large layer of heavily burnt material in the northwest that extends across into 64.72. As in the previous phase, the central area yielded substantial quantities of amorphous copper fragments, typically

[19] For discussion of these finds see; (Dardeniz, 2018, 2015, 2014).

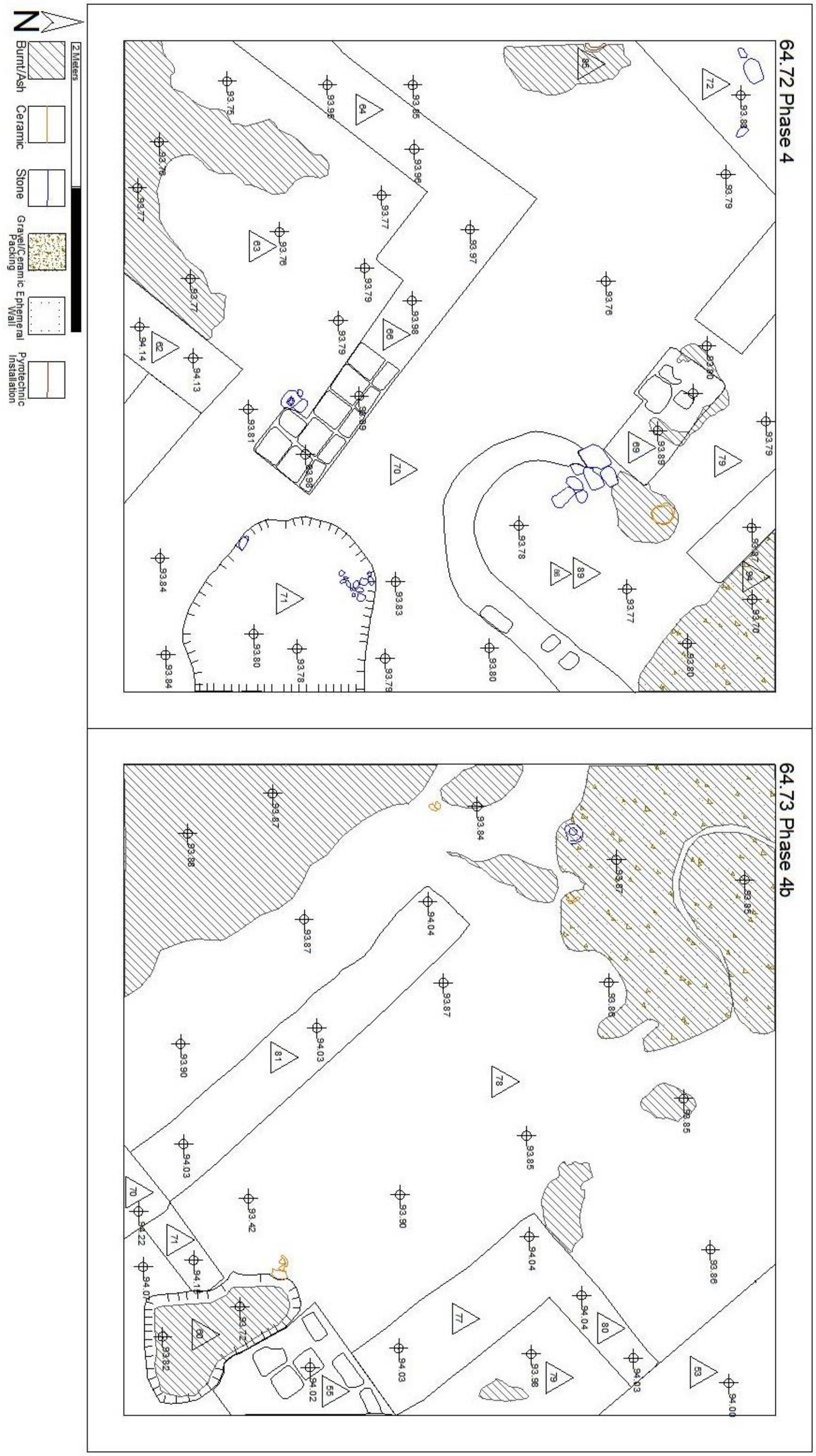



Figure 3-13: Top Plan, 64.72, 73 Phase 4b. © 2020 Alalakh Archives

identified as casting spill. This phase also marks the first point when the southwest and southeast corners of 64.73 and 64.72, respectively, become a clearly defined courtyard. Finally, in terms of the ceramic assemblage, in addition to the shift toward a more standardized assemblage mentioned above, we see a rise in the quantities of Cypriot imports in this area.

*Locus 78 (L78), Context Key 64_73_78_268:* This space represents roughly the same type of area as seen in Phase 5. A single sample was drawn from here, AT23469.

<u>Local Phase 4a (Figure 3-14):</u> At this point, the architecture in 64.73 displays a better quality of construction and a more clearly articulated ground plan than in previous phases. The central area, Locus 63, now appears to be an interior domestic space or a roofed stall, open on its northeast side. Unfortunately, it remains somewhat unclear as to whether Locus 74 extended all the way to the pavement, Locus 76. On the northwest side of Locus 67, two rooms were constructed, one of which housed a potential hearth, Locus 75.[20] In the courtyard of the structure, in the southwest corner of the square and extending west into 64.72, there is a continuation of craft activity as well as the installation of a stone and ceramic pavement. Large amounts of ash, as well as slag, metal fragments and objects, glass fragments, glass beads, carnelian beads, carnelian debitage, bead blanks, flint debitage, and obsidian characterize

[20] Normally this is a clear-cut identification to make, but the general cleanliness of the surrounding area makes it a somewhat more difficult decision. That said, given that it was located indoors, it probably would have been cleaned more regularly and thoroughly.

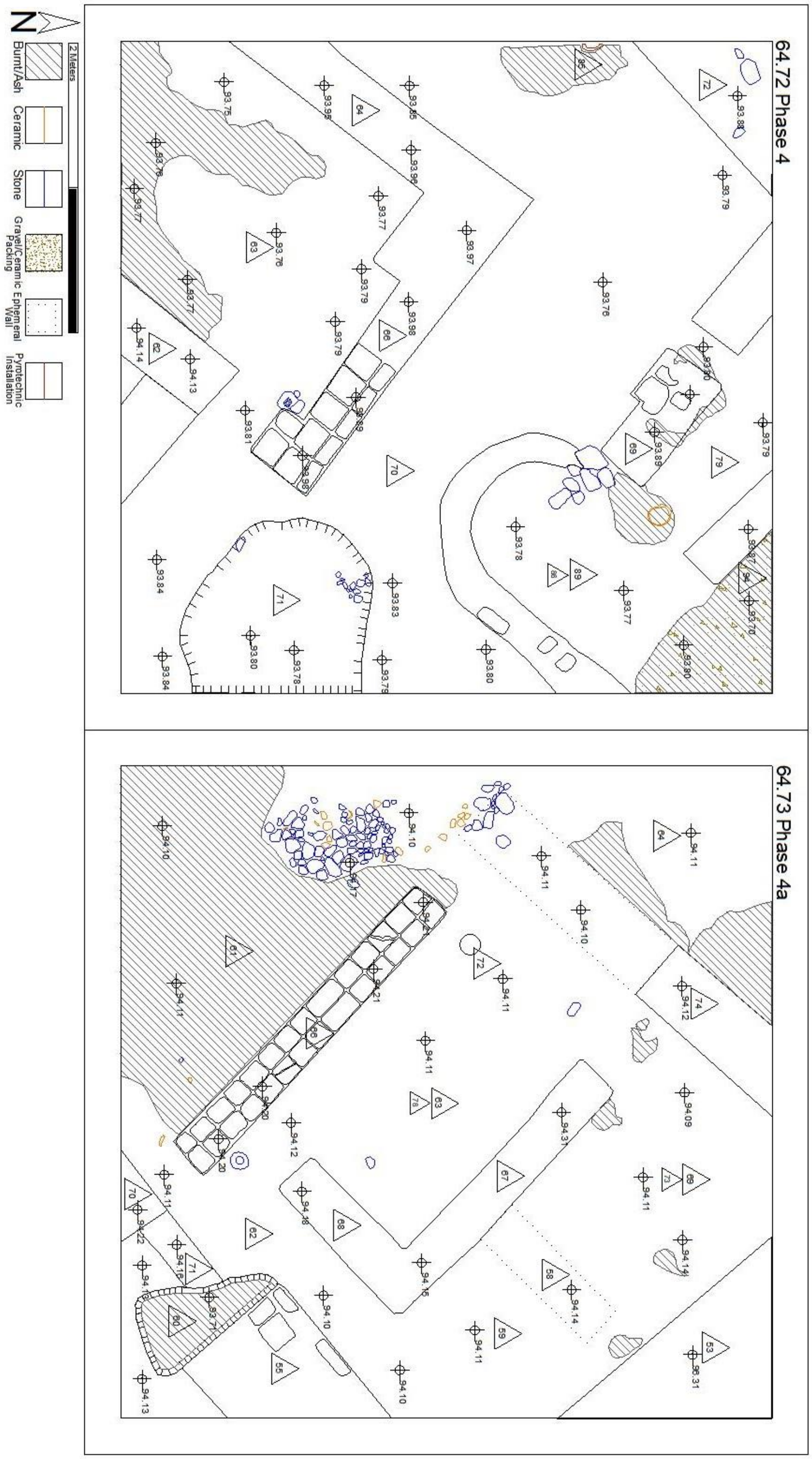



Figure 3-14: Top Plan 64.72,73 Phase 4a. © 2020 Alalakh Archives

the deposit.[21] Finally, we see a massive spike in the quantities of Cypriot ceramics in this phase, primarily consisting of White Slip II, Base Ring II, and Cypriot Monochrome.

*Locus 73 (L73), Context Key 64_73_73_245:* L73 refers to the area north of Locus 67 prior to the construction of Locus 58, which divided the space into two rooms. This area housed the possible hearth, Locus 75, and yielded a small amount of glass and metal. A lump of copper (AT22853) was sampled from this context.

*Locus 64 (L64), Context Keys 64_73_64_ 230:* L64 represents something of a challenge in interpretation due to the remains of Locus 74, which appears to have actually bisected L64, enclosing L63 on its northwest side. While it was never possible to trace the mudbricks of Locus 74, it does seem to have left a rather clear definition in the character of the soil, with the region to its northwest being of a decidedly ashier, mixed composition. This would also seem to be borne out by the substantial quantities of slag, glass, and metal from this section of the locus. A similar situation obtains for this area in Phase 3b (see below).

*Locus 63 (L63), Context Keys 64_73_63_218 and 248:* This space generally seems to have constituted an interior or semi-interior domestic space. Non-ceramic finds consisted primarily of glass and small amounts of slag and metal.

[21] If we can associate the individuals buried in 64.72 with these production activities, the dental wear patterns associated with these people are typical of certain types of leatherworking and rope making (Rula Shafiq, Personal Communication 2018).

Two samples were taken from this context, an amorphous piece of copper (AT21719) and a flow of slag adhered to material typical of *tandır* ovens (AT22869).

*Locus 61 (L61), Context Keys 64_73_61_221 and 228:* L61 constitutes the courtyard area in the southwest of the square. Part of a shaft (AT21743) and an awl (AT21778) were sampled from this context.

3.3.3.3 Local Phase 3 (Squares 64.72, 64.82, 64.73, 64.83, and 64.94): Local Phase 3, revealed across the entirety of Area 4[22], represents the most complete realization of those architectural features seen in earlier phases of occupation.[23] Although there are some reorientations and modifications to the building, reflecting a greater degree of planning and better quality of construction, the features seen in 64.72 and 64.73 tend to largely agree with the architecture of the preceding Phase 4. In 64.72, there is a clearer delimitation of rooms and separation of space. In 64.73, the plan remains open, giving the continued impression of a partially roofed space opening onto a courtyard. The courtyard itself, still represented in both 64.72 and 64.73, as well as in the very northeastern corner of 64.82, continues to contain crafting debris, although its quantities diminish later in the phase. Overall, Phase 3 shows continued metallurgical activity, though its locus appears to have shifted to other areas of the compound, with the previous (apparent) center now becoming more domestic in nature. Two sub-phases of Phase 3 are present across Area

[22] While there are indications of Phase 3 architecture in 64.84, they are so heavily disturbed by the foundations of the Southern Fortress that it is nearly impossible to parse the architecture, let alone the types of activity taking place there.
[23] Local Phase 3 in squares 64.72 and 64.82 has been published in detail by Akar (2019, pp. 51–59). In that publication, this structure is referred to as Building 2008-1.

4,[24] though there is a case to be made for several apparent episodes of modification in 64.73 that will be discussed below.

*Building 2008-1:* As mentioned above, this structure was partially excavated in 2008 and has now been exposed over all of Area 4. It forms a contiguous compound with at least ten rooms as well as a large central courtyard, though a second substantial outdoor space can be posited in 64.94. The western part of the exposure in 64.72 and 64.82 appears to be largely domestic in character with some metallurgical and other production debris, while 64.94 and 64.82 host a variety of pyrotechnical installations and have generated substantial quantities of slag and other material. In 64.82, we see the southern edge of the building facing onto a NW-SE oriented street, which generated a massive quantity of industrial debris in both phases 3a and 3b.

> <u>Local Phase 3b (Figure 3-15):</u> The plan of Phase 3b displays a more closed organization than we see in the subsequent 3a. Square 64.82 is characterized by several rooms along the south wall of the compound, one of which (Locus 62 in 64.82, Locus 41 in 64.72) appears to have been reachable only via access through a stairway, probably located in 64.82, Locus 61. The remaining two rooms (Loci 56 and 50) were accessible from the central courtyard. Locus 56 generated a substantial amount of metal debris, while 50 housed both a pyrotechnic installation, metal debris, and some slag. In neighboring 64.83, we are presented only with the tops of the 3b walls, so it is impossible to remark

[24] Though incompletely excavated in 64.83.

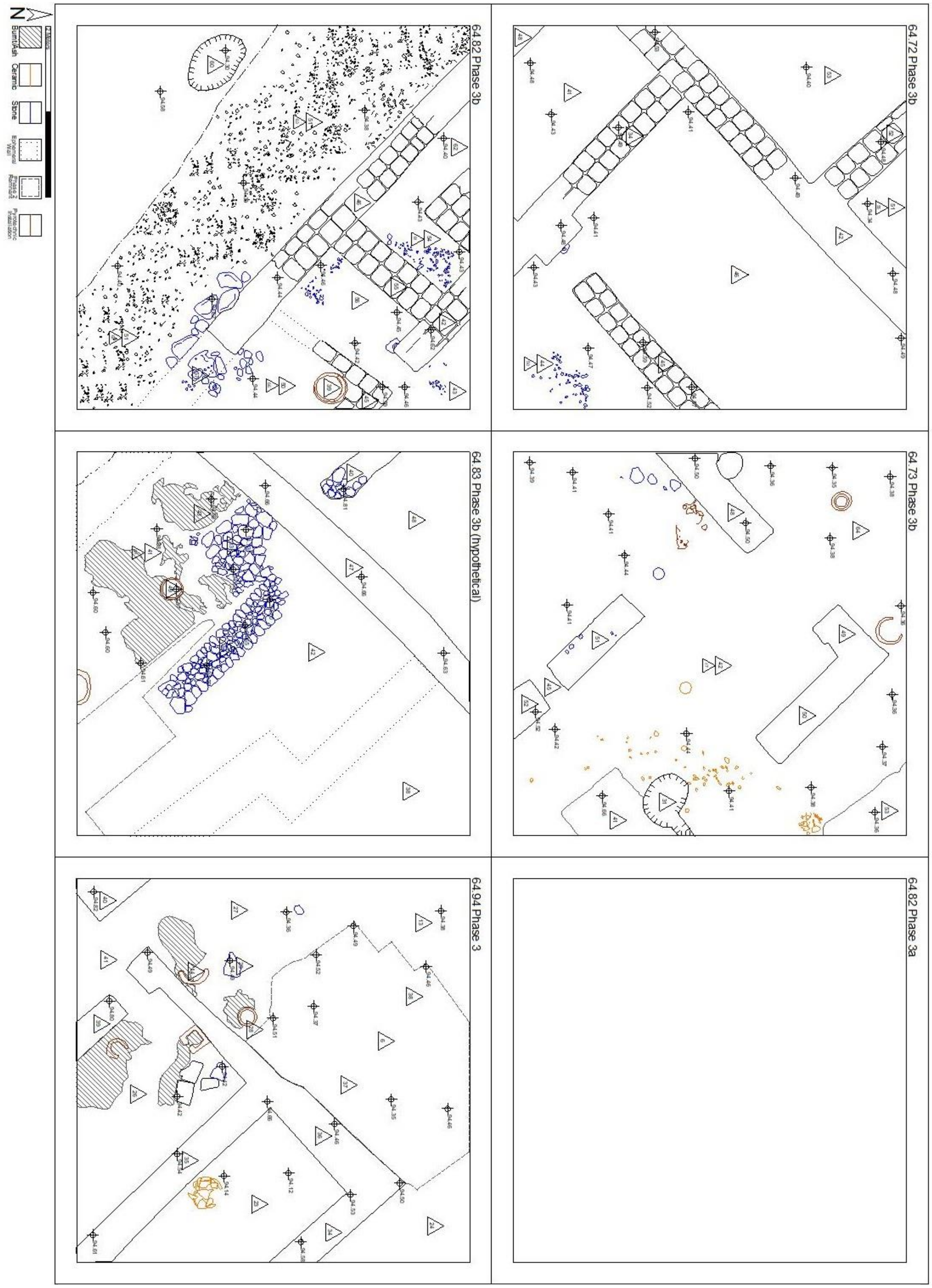



Figure 3-15: Top Plan, Area 4 Phase 3b. © 2020 Alalakh Archives

n its layout with any certainty, but it seems probable that it follows a similar pattern of being a more open plan in the subsequent 3a.

Four separate rooms and part of the central courtyard characterize 64.72 in this phase. While the subsidiary rooms to the north, west, and south tended to be relatively clean, the central room (Locus 37/46) produced stone tools, some slag, as well as metal objects and amorphous fragments. Meanwhile, 64.73 is characterized by three walls that never seem to meet – a point borne by *in situ* features and artifacts – forming what might best be described as a crude portico. Both the north and southwest corners consist of outdoor space, with the former also housing a pyrotechnical feature. At this point, it no longer appears that the portion of the structure revealed in 64.73 is involved in substantial production activity, having only yielded a few metal objects and fragments.

An unusual quirk of Phase 3b in 64.73 is that the floorplan we were able to recover appears to lie atop the remains of walls that articulate with the Phase 3a architecture of 64.72 (Figure 3-16). It is a general feature of construction practices at Atchana that people would often cut walls down to 20-25cm, using the wall material to seal a floor and level the building surface, before using the remaining portion of the previous walls for the foundations of the new construction. In this case, the walls of the previous structure may have been reduced to an even more substantial degree. As can be seen in Figure 3-16, the outlines of walls articulating with the 64.72 Phase 3a architecture are clearly visible, and a small segment of that wall can also be seen preserved where

Locus 48 meets the west baulk. However, the depth to which these walls were preserved in 64.73 was negligible, appearing only ephemerally in the course of excavation, and disappearing in a similarly abrupt fashion.

Figure 3-16: Image showing traces of the hypothetical Phase 3a3 in 64.73. The raised area north of the juncture between Locus 48 and the west baulk could be a remnant of a wall running SW-NE, with an extension running to the NW. The interior corner of this join is just SW of the small raised platform in the NW corner of the square. Meanwhile, traces of a wall running NW-SE underneath Loci 48, 51, and 52 are visible, with a stone bowl and remnants of a tandır overlaying its southern edge. Finally, part of another NW-SE oriented wall appears to have comprised part of the 3a2/3b Loci 49 and 50. Photo Credit: Murat Akar. © 2020 Alalakh Archives

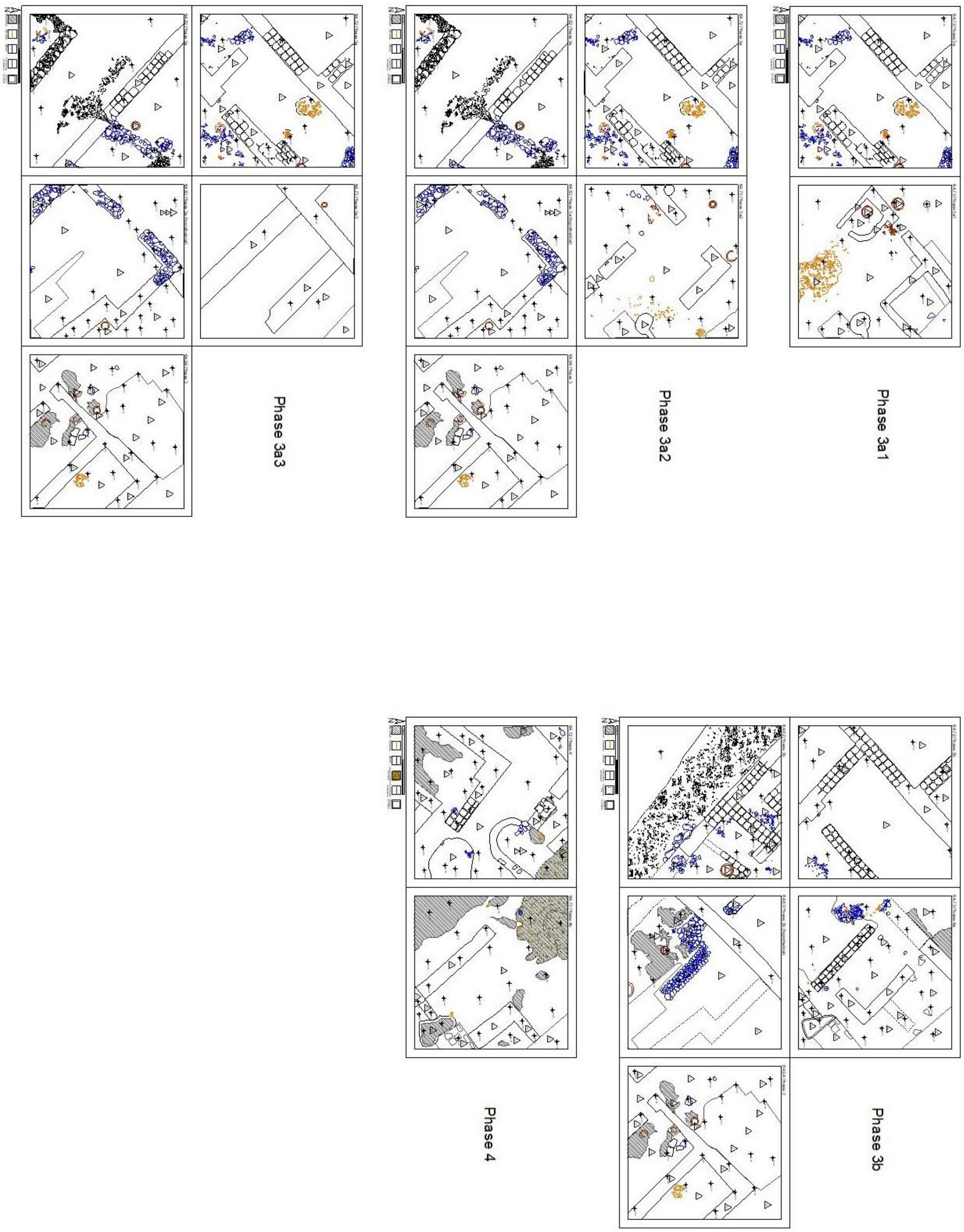



Figure 3-17: Sequence of phases in Area 4. Phase 3a3 in 64.73 would then been the inserted phase that was largely levelled to allow for the construction of Phase 3a2. Phase 3a1, meanwhile, would then be a structure built within the ruins of the earlier compound prior to the Southern Fortress. © 2020 Alalakh Archives

It is obviously impossible to be sure at this point,[25] but such an explanation, based on non-synchronous architectural modifications, does account for the somewhat unusual architectural articulation between 64.72, 64.73, and 64.83 at similar elevations. As such, it may be possible to suggest that in 64.73, we have phases 3a1, 3a2 and 3a3, with the current 3b plan actually representing 3a2, while the ephemeral phase would be 3a3 and 3a1 would be our current Phase 3a (Figure 3-17). In 64.72, meanwhile, the 3a-3b division is reasonably secure. In this case, 64.72 3b could be said to coexist with the 4a modification of 64.73, which is suggested to a certain extent in the original section drawings and by Locus 57, meaning that 64.72 3b extends some ~30cm deeper than currently shown. 64.72 3a would then coincide with our faintly suggested 3a3 and 3a2, while 3a1 does not seem to be represented anywhere else in Area 4. Looking at the bases of the walls of the Southern Fortress there is a strong suggestion that 64.73 became a local high point, which can be accounted for by the construction of 3a1, which already resembles a divergence in character from the preceding phases and does not articulate well with any other recovered architecture.

*64.72 Phase 3b Loci:*

*Locus 55 (L55), Context Keys 64_72_55_204 and 206:* Locus 55, lots 204 and 206 represent parts of a very thin layer between phases 4a and 3b, underlying loci 46 and 51. This layer produced substantial quantities of metal and slag

[25] Two points bear emphasis here. First, this reconstruction is speculative, but worth mentioning due to previous instances of similar staggered modifications (i.e. 64.72 Phase 4 vs. 64.73 Phases 4a and 4b). Second, these are merely my initial thoughts on this matter; even if true, these modifications do not substantially change the interpretation of the structure. The final revision of this sequence will be published in Volume 3 of the Tell Atchana publications, currently in the planning stages.

finds. A sheet fragment (AT8904) and two pieces of wire (AT8906 and AT8915) were sampled from here.

*Locus 50 (L50), Context Keys 64_72_50_190 and 194:* Locus 50 is the portion of the courtyard of Building 2008-1 located in the southeast corner of 64.72. Part of a metal vessel (AT8002) and a decorative element (AT8048) were sampled.

*Locus 46 (L46), Context Keys 64_72_46_188, 191, and 192:* Locus 46 is the long main room extending through the center of 64.72 and yielded metals, slags, and glass beads. Several pins (AT7294, AT7288, and AT8037), amorphous fragments (AT8040, AT8020, and AT7297), and a slag fragment (AT8019) were sampled from this context.

*64.73 Phase 3b Loci:*

*Locus 64 (L64), Context Key 64_73_64_211:* This refers to the same area as L64 above, except that Lot 211 is associated with Phase 3b. Slag fragment (AT21393) originated from here.

*Locus 47 (L47), Context Keys 64_73_47_207 and 193:* While Locus 47 refers to the general floor area of Phase 3b, Lots 207 and 193 pertain specifically to the courtyard space in the southwest corner. A shaft (AT21332) and an amorphous fragment (AT21374) were sampled from here.

*Locus 42 (L42), Context Keys 64_73_42_177 and 184:* These contexts refer to the central space in the square. An awl (AT18494) and a slag fragment (AT18814) were sampled from here.

*64.82 Phase 3b Loci:*

*Locus 66 (L66), Context Key 64_82_66_220:* L66, Lot 220 refers to the southern portion of the room originally represented by Locus 50 at the lowest level of Phase 3b. A single shaft piece (AT8666) was sampled from here.

*Locus 63 (L63), Context Keys 64_82_63_224, 222, and 217:* L63 is the street area that runs along the southern face of Building 2008-1, while Lots 224, 222, and 217 derive from its earlier phases at around 94.30 masl. While a street context typically does not represent the most secure of environments, the sheer volume of material here and the clear association of activity spaces within the building with metallurgy made this is reasonable context for sampling. Furthermore, the volume of industrial debris deposited here points to some rather interesting patterns of discard, suggesting a clear tendency to dispose of industrial materials at a different part of the site. Thus, while the quantities of industrial debris excavated from Building 2008-1 may be limited when compared to workshop contexts elsewhere (i.e. Cyprus), it is entirely possible to posit a greater level of production than we might otherwise assume. From this context, slags (AT8699, AT8686, AT8680, AT8672, AT8620, and AT8491) and several metal objects and fragments (AT8676, AT8498, and AT8465) were sampled.

*Locus 60 (L60), Context Key 64_82_60_195:* Locus 60 is a small pit underneath the remains of Building 2006-3. It yielded a few metal and slag fragments, of which slag fragment AT7762 was sampled.

*Locus 54 (L54), Context Key 64_82_54_203:* Locus 54, also referred to as Locus 61, represents one of the small rooms situated along the southern wall of the building. The deposit here consisted of a few metal objects, beads, and glass. Of these, a projectile point (AT8237) was sampled.

*Locus 51 (L51), Context Key 64_82_51_202, 200, and 184:* Same as L63 from approximately 94.36 – 94.30 masl. Slags AT8236, AT8232, and AT8061, metal fragment AT8089, and gold fragment AT7249 originated from here.

*Locus 50 (L50), Context Key 64_82_50_208:* L50 represents the easternmost room along the southern wall of Building 2008-1. In addition to housing a pyrotechnical installation, this context also yielded metal fragments and some slag, as well as a basalt grinding stone. Metal fragment AT8322 derived from this context.

Local Phase 3a (Figure 3-18): Phase 3a has thus far yielded our most complete plan for Building 2008-1. While we can posit that the portion of the structure visible in 64.83 probably remains largely similar to its 3a configuration in 3b, this must be confirmed by excavation. At present, it seems probable that what may have been two rooms separated by a stone wall in the middle of the square (Locus 34) was unified into a single large room, while the northwest and northeast corners were outdoor space. The room toward the southwest corner of the square yielded substantial quantities of ash, but most metallurgical finds were concentrated in the northeast corner in the outdoor space that continued into 64.94. In 64.94, a substantial portion of the structure, containing two rooms and clear pyrotechnical installations, has been uncovered, though the

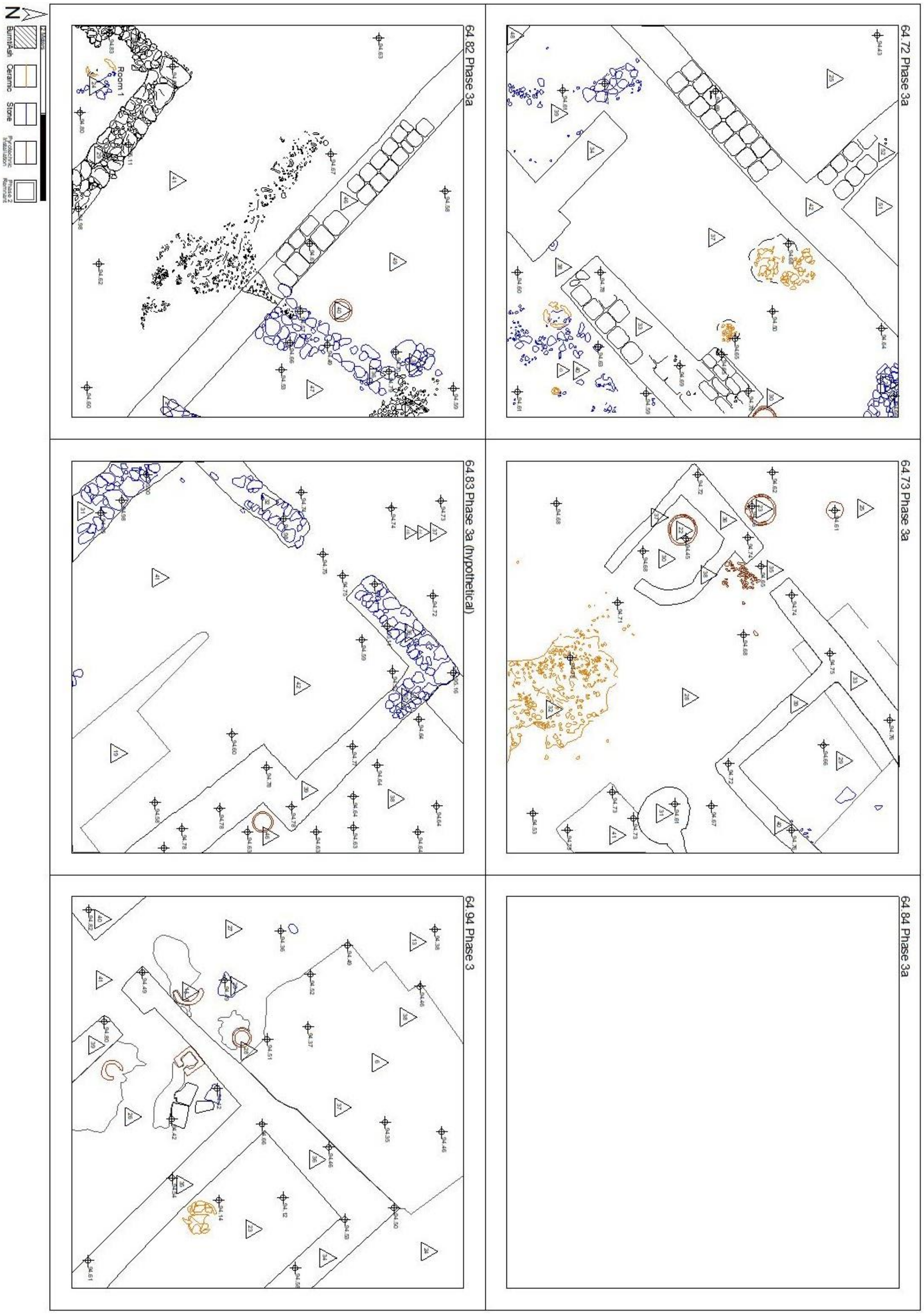



Figure 3-18: Top Plan, Area 4 Phase 3a. © 2020 Alalakh Archives

Southern Fortress. Together, both trenches produced substantial quantities of metallurgical debris.

In 64.82, the row of rooms that had been situated along the southern wall of the building was no longer in existence. Instead, it appears that all the area north of Locus 46 became part of a large courtyard area. One pyrotechnical installation was in this expanse next to a drain that went through Locus 46. By this point, however, production related activity in this part of 2008-1 appears to have ceased. In 64.72, we see an essentially similar plan to that seen in 3b, with a large room at the center of the square, this time connected to the room on its south, while the northeastern corner constitutes outdoor space. The eastern wall of the large room (Locus 33) is built in a rather different style from the rest of the structure, being much thicker and utilizing bricks both laid flat as well as on-edge. In contrast to 64.82, we continue to see quantities of slag and metal debris, particularly from the central room (Locus 37), as well as stone working debris and stone tools. In some respects, 64.72 is now reminiscent of what we have seen in 64.73 for some time now, namely that it appears like a connected series of semi-roofed spaces and courtyards.

Phase 3a in 64.73 follows roughly similar contours to the preceding Phase 3b, although, as mentioned above, its articulation with the rest of the Area 4 3a architecture is problematic. Overall, it appears that the square is generally divided into what may loosely, and very tentatively, be termed inner and outer courtyards. Locus 28 would seem to represent the inner portion, also housing a small enclosure for a pyrotechnic installation, a large scatter of broken pottery and a pit, while a small room occupies the northeastern corner of the area. Locus 25, comprising the northwestern corner of the square would then appear to be external, also housing a pyrotechnic installation and little else. A few metal fragments derived from this latter context. As the most clearly production related portion of Area 4 for Phase 3a, all samples were taken from square 64.94.

*Locus 27 (L27), Context Key 64_94_27_131:* Locus 27 refers to the outdoor space that joins with the outdoor area in the eastern portion of 64.82 and the southern portion of 64.73. Substantial ashy deposits as well as two pyrotechnical installations were recovered here. A small fragment (AT19177) was sampled from this context.

*Locus 26 (L26), Context Keys 64_94_26_128, 124, 112, and 101:* Locus 26 represents a room located in the southwest corner of 64.94. Along the eastern wall, a small square pyrotechnical installation of mud was situated with large mudbricks placed immediately to its east with a substantial trail of ash running along their face. The rest of the room also yielded considerable quantities of burnt material. Matte fragment AT18636, sheet fragment AT18608, amorphous fragments AT18609, AT18635, and AT19172, and shaft fragment AT19162 derived from this context.

*Locus 23 (L23), Context Key 64_94_23_123:* Locus 23 is another room adjacent to L26. It is not currently known how the room rooms join, though they are clearly part of the same structure. Slag AT19157 and shaft fragment AT19158 derived from here.

3.3.3.4 Local Phase 2: Local Phase 2 (Figure 3-19) in Area 4 refers to the construction and use of the Southern Fortress in the final period of major occupation in this part of the city. The structure – Building 2006-2 in Alalakh, Volume 2 (Akar, 2019, pp. 314–317) – characterizing this phase has been almost entirely excavated across Area 4, though it appears as though it could continue further to the northwest. While the structure shows a variety of use contexts throughout our exposures, the area excavated in 64.94 is of primary interest for the current study, having produced a substantial density of metallurgical finds. In particular, the eastern portion of the square has yielded a variety of pyrotechnical installations in an outdoor space accompanied by metal fragments and slag. Because of its outdoor nature and constant accumulation of material, it seems reasonable to suggest that this context be more generally labelled as Phase 2, spanning across sub-phases 2a and 2b of Building 2006-2.

*Locus 13 (L13), Context Key 64_94_13_35:* Locus 13 represents the Local Phase 2b portion of the large central room of Building 2006-2 located in 64.94. A large, pointed shaft – possibly a blade blank (AT4318) – was sampled from this context.

*Locus 10 (L10), Context Key 64_94_10_38:* Locus 10 represents a small section of the southern portion of L13 that was, at one point, thought to be a thin dividing wall that never materialized. Matte fragment AT4327 derived from this area.

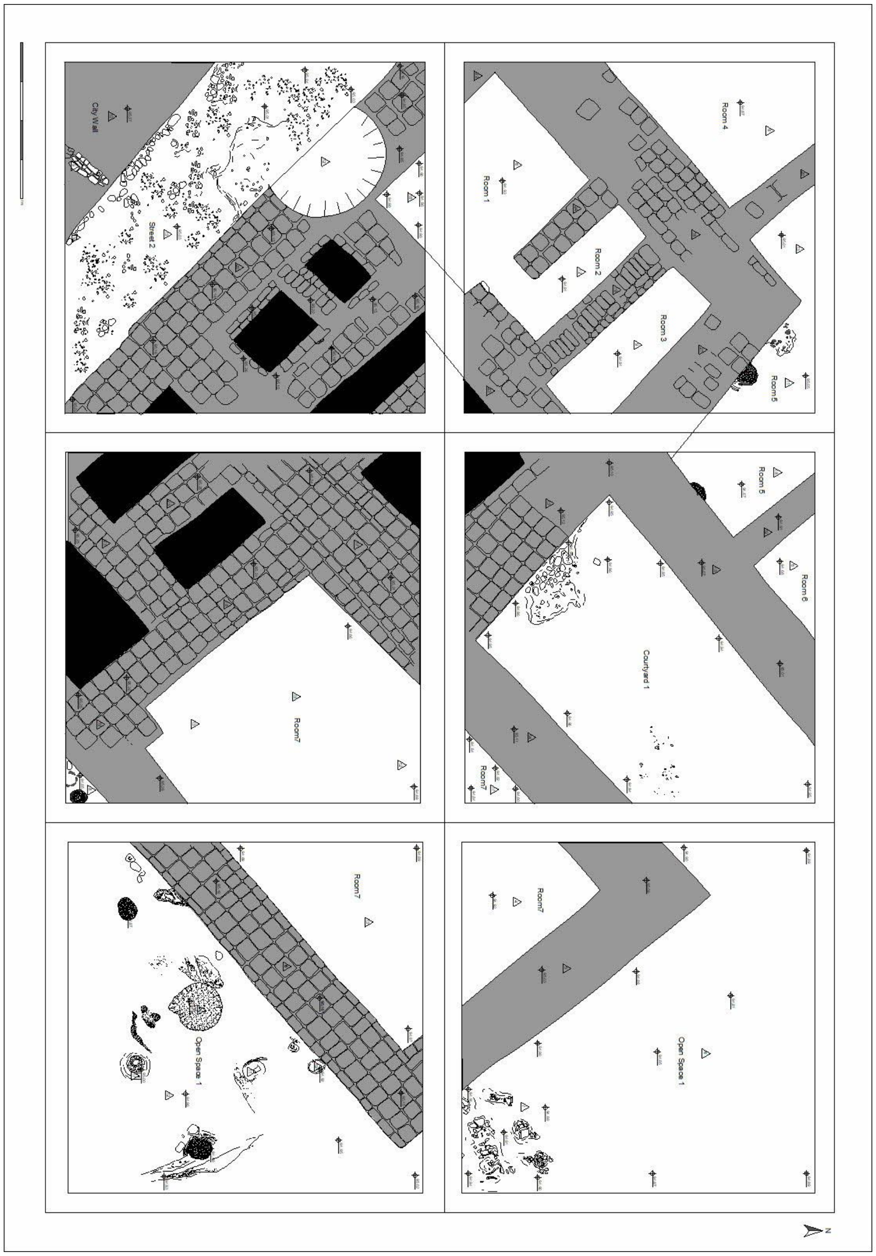


Figure 3-19: Top Plan, Area 4 Phase 2. Plan Credit: Özgecan Aydın and Egemen Kaya. © 2020 Alalakh Archives

*Locus 9 (L9), Context Key 64_94_9_30:* Locus 9 is the area immediately south of L10. Sheet fragment AT4148 and amorphous fragment AT4147 were excavated from this location.

*Locus 5 (L5), Context Key 64_94_5_21:* Locus 5 was a pit dug into the outdoor space east of 2006-2. It housed a 5kg deposit of slag from which three fragments (all under AT4109) were taken, as well as a metal rim fragment (AT4113).

*Locus 4 (L4), Context Keys 64_94_4_33 and 18:* Locus 4 refers to the general expanse of the outdoor space east of 2006-2. Sheet fragments (AT4049), amorphous fragments (AT4101), and slags (AT4309, AT4048, and AT4100) were sampled from here.

*Locus 3 (L3), Context Keys 64_94_3_28 and 22:* Locus 3, Lots 28 and 22 refer to the same space as L13, but in Local Phase 2a. Sheet fragments (AT4123) and shaft fragments (AT4139) derived from this context.

## 3.4 Concluding Remarks

Having presented all the sampled contexts with their stratigraphic associations and phasing, the general impression across all areas of the site discussed is initially one of general continuity and development. As we have seen in Area 1 North, that portion of the Level IV Castle investigated by the Yener campaigns displays a stubborn adherence to its initial architectural plan, while also maintaining its character as a service wing of the administrative sector of the site. Area 1 South, in the span prior to the Hittite takeover of Alalakh, also displays a similar continuity, though the emerging image in 42.10, while reflecting general spatial similarity, may show a certain flexibility in function. In Area 4, we see a similar pattern of continuity in use of space, though the sense of a developing and increasingly prosperous part of the city is palpable. Tentatively, we may suggest that this process extends from the latter portion of Period 5 through to the final stages of Period 3, when it appears that we begin to see a breakdown in the urban fabric of Area 4.

After the imposition of Hittite dominion during Period 2, signaled by the construction of the Northern and Southern Fortresses, we might suggest a divergence in the fortunes of each area. Area 1 North, the former seat of royal authority of the city, becomes the site of what can only be described as a massive demonstration of power on the part of the new regime. Meanwhile, the portion of Area 1 South represented by 42.10 appears to remain largely untouched, while in 42.29 we see what had been an elite dump overlain with new construction. Area 4, which appears to have experienced a decline in the years immediately preceding Period 2, becomes the site of a more modest imperial project. It is not clear what happened to the inhabitants of the earlier structures in this area, though based on the activity seen to the east of the Southern Fortress, they may have simply moved – this is a question for further excavation. For the final stages of occupation at the site, Area 1 South is our only solidly contextualized clue, suggesting a diminished, but continuing, occupation at the summit of the mound into the Iron Age.

Now that I have laid out the development of the relevant areas of Tell Atchana, running from the later stages of the LBI occupation to the final years of the LBII, the next chapter will be concerned with two points. Of significant importance is the issue of lowland-highland relations and their implications for resource access. This will concern the Near Eastern milieu generally, as well as the specific circumstances of the south-central Taurus and Amanus mountains neighboring Tell Atchana in particular. In addition, I will consider the social position of metallurgical communities through several ethnographic and historico-mythological examples to discuss their role in mediating between sedentary and semi-sedentary populations.

# 4 Highland and Metallurgical Communities: Some Socio-Cultural Issues in Resource Access

As the first step in the productive process, resource procurement is a critical aspect of technological systems. For metallurgy, not only do the ores available dictate the general contours of the *chaîne opératoire* used in their processing such as the removal of sulfur or addition of flux to facilitate slag formation, their associated accessory minerals (i.e. arsenic minerals) can have a significant impact on the final composition of the metal, manifesting in technological styles adapted to certain deposits. Beyond this, the often-remote location of many ore deposits poses its own series of problems for procurement networks. These include the presence of potentially hostile populations, not to mention more mundane considerations such as sustenance, labor procurement, or even knowing where to look to find ore resources. These factors apply equally for just about any montane resource, not just metals. With these considerations in mind, it is worth hypothesizing that ancient primary metallurgy was to a significant degree carried out by indigenous highland groups, while lowland state industries were primarily secondary in nature.

This was in fact demonstrated for the south-central Taurus during the EBA by Yener (2000), where she elucidated a two-tier production model of ancient metallurgy in relation to tin production at Göltepe. Signifying the degree to which technological systems are particularistically constructed, however, the evidence presented in this study points to primary production in the Area 4 workshop of the LBA lowland center of Tell Atchana, utilizing ores that originated from a handful of locales nearby to those very regions Prof. Yener surveyed during the 1980's and 90's (Yener and Özbal, 1987; Yener and Vandiver, 1993). Based on my analyses, these ores formed part of a small-scale technological system based on the working of montane resources that included a highly specific mode of bronze production. The specificity of this system suggests that the individuals in Area 4 had some connection to highland communities, and may have been former highland dwellers themselves, in order to facilitate access to these resources. That this segment of the industry demonstrates significant independence from the palace sector suggests that the major lowland authority could not or would not involve itself in this primary production network.

Taking this as a working hypothesis, it is necessary to consider population dynamics within highland regions of the Near East generally, and the south-central Taurus and Amanus in particular, as well as the general character of metallurgical communities and how the practice of technological styles aids in the creation of exclusive occupational groups that sometimes form occupational ethnicities. On the one hand, highland populations not engaged in metallurgy may serve to hinder the access of lowland states to valuable montane resources, making direct exploitation of such resources by lowland populations on a long-term basis economically risky. On the other hand, social networks and specific knowledge linked to occupational groups may allow members who have relocated to lowland communities to continue to access such valuable resources. In this chapter I will use Scott's (2009) analysis of southeast Asian highland communities as a starting point for discussing these relationships that cut across lowland-highland and urban-rural divides, followed by a discussion of Near Eastern highland populations and their relationship to the state, closing with a discussion of ethnographic examples of metallurgical communities that constitute occupational ethnicities.

## 4.1 The Stone and the Sown

When examining the urban-rural-marginal divide[1] we often homogenize the political landscape at the expense of real variation in the archaeological record.[2] Where the concept of urban-rural marks a difference between agglomerated urban settlements characterized by divisions of labor, craft specialists, and a developed central administration, the rural is thought of in terms of outlying settlements providing subsistence goods and labor (Fall et al., 1998; McMahon, 2019, pp. 7–8). If we discuss a realm beyond the rural, we often conceive of these areas as marginal landscapes occupied by uncivilized peoples of little consequence. For the more economically minded, the peripheries are relevant primarily as sources of valuable raw materials to be worked in lowland centers and pools of labor (Algaze, 2018, 1993, pp. 61–84). In short, the relationships between expansionist urban centers, their immediate rural surrounds, and further outlying areas are still largely conceptualized in core-periphery terms[3] where "it is economic dominance that is the irreducible common denominator of imperial systems" (Algaze, 1993, p. 9).

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[1] See, Woolley (1936, p. 126): "In antiquity the mountains were densely wooded; their inhabitants must have been wood-cutters, huntsmen and perhaps miners (since both gold and copper are to be found in the hills), men who were strangers to town life, of whose rude and temporary dwellings no trace is likely to remain. It is certain that the civilized people of inland cities left the hills severely alone." Though probably partially correct, for Woolley this is an excuse to not research or think about these areas.

[2] To use Barfield's (2010, pp. 67–71) terminology, we often apply an "American cheese" model of states to the ancient world, when the political landscape was actually configured more akin to swiss cheese.

[3] Core-periphery theories represent a mainstay of studies on ancient urbanism concerned with relationships between economically, socially, and politically dominant centers and outlying areas from which they extract labor and resources. There exists a substantial body of literature on this topic that falls outside the immediately purview of this project, however, for general summaries see; (Algaze, 1993, pp. 6–10; Kardulias and Hall, 2008)

Several scholars have challenged this tendency, especially as it applies to highland regions. In his seminal *Archaeological Landscapes of the Near East*, Wilkinson (2003, pp. 184–186) places a distinct emphasis on the highly textured and granular nature of these landscapes and their significant potential for the development of diversified and specialized communities that occupy the multitude of ecological niches that they host. As Shaw (1990) notes in his work on communities in rough Cilicia during the Roman period, not only do highlands hold the potential to foster unique forms of economic and social organization, the capacity of lowland states to actually capitalize on highland zones was often quite limited. It is worth quoting part of an account of Cicero's campaign into the Amanus at length:

> "After camping for four days on the Pyramos River near Issus (13-17 October), Cicero sent his troops around the surrounding regions systematically to destroy rural settlements and buildings. He then advanced to attack the mountain village of Pindenissum, one of the fortified strongholds of the 'free Cilicians', so-named because of their tradition of perpetual armed resistance to lowland powers. They are likened by Cicero to wild savages beyond the pale of civilization. These Free Cilicians had never given obedience to any king. Their land was a haven of freedom for oppressed plains dwellers, and a shelter for fugitives from the lowlands." (Shaw, 1990, p. 225)

The political ecology (cf. Morehart et al., 2018, pp. 9, 11–12) formed by the highland-lowland relationship has been most thoroughly discussed by Scott (2009) in his evaluation of economic, political, and cultural dynamics between highland and lowland communities in Southeast Asia. Among his more salient observations are the points that lowland agrarian states were typically incapable of exerting lasting and direct hard power into surrounding highland regions, that they were often dependent on cooperative trade with highland populations for their most economically valuable goods, that there was often significant population flux between the highlands and lowlands and that they constituted their social structures in opposition to stat-based hierarchy and taxation systems. Accordingly, distance from the political center marked a continuum of "stateness", where beyond an immediate core area the capacity of the state to exert influence rapidly dropped off. As a result, subjects had some degree of agency in choosing their level of engagement with the state and could opt to dissociate themselves if circumstances were no longer beneficial. Meanwhile, at least the first two of Scott's propositions find support in Yener's (2000) *The Domestication of Metals* wherein she demonstrates that, far from being upland outposts of lowland centers or subservient backwaters, highland communities were fully capable of constituting substantial settlements with economic strategies well suited to their environmental niches.

### *4.1.1 Highland Communities*

Though it may appear unproblematic, the definition of highlands is especially relevant when confronting the geography of Turkey, given that the entire country is highland when compared to the landscapes of Syria or Iraq. As Frangipane (2010, p. 84) notes in reference to the development of complex society on the Anatolian plateau during the Chalcolithic and Early Bronze Age, early state entities formed within a "weakly hierarchical society made up of small territorial units in a basically mountainous environment." This approximates the assessment of highland societies provided above, but as Scott (2009, p. 167) has noted, just as there are degrees of "stateness" there are also degrees of "highlandness". While calling the plateau a highland zone is factually correct in comparison to the plains of Syria and Iraq, when examined against the surrounding mountains, it is anything but highland.[4] Within this schema, sedentary societies

[4] Compared to the Anatolian Plateau (600-1200masl), the Taurus Mountains reach 3,756masl, the Pontic Mountains reach 3,937masl, and the Amanus (not adjacent to the plateau) reach 2,240masl. The regions discussed by Scott (2009) are between 300-4,000masl. The Anatolian ranges tend to be smaller in their areal extent.

occupying relatively open landscapes, whether that is the Hittites or the Mesopotamians, are in a similar political position relative to populations dwelling in the mountains.

Thus, when considering the topic of metallurgy in the Near East generally, and in Turkey in particular, the importance of the highland-lowland relationship gains emphasis. Within Turkey, most ore deposits are located in the mountains surrounding the plateau with only a few exceptions (Pirajno et al., 2019; Seeliger et al., 1985; Wagner et al., 1989, 1986).[5] Therefore, in terms of understanding the types of relationships that could come into play in procurement networks, it is important to understand how (comparatively) lowland societies understood their highland neighbors and how they interacted. Going back to at least the 3rd millennium BC in "Gul-AN and the Seventeen Kings against Naram-Sin" and the "Cuthean Legend", the relationship is violent, adversarial, and derogatory (Westenholz, 1997, pp. 222, 255, 309–313). In the former text it is said:

> "Gula-AN, king of Gutium, […], whom I [defeated] in strong battle […], and whom I had released to return to his land (but) PN [he joined], he who is not flesh nor blood, verily he is […]. In the Amanus the cedar mountain his oracles [he consulted]. Before the great divides of the [silver(?)] mountains, its gate he captured[6] and stealthily in the night he attacked and my armed forces he did kill, he did decimate, and he did [trample down]." (RA 70:14-22)

Because this is a literary text, it should not necessarily be taken to recount real events, although they may have spurred its composition. Instead, it should be read as a reflection of how Mesopotamian society conceived of the people inhabiting highland regions generally, while the

[5] Anecdotally, during the 2019 field season in Hatay I expressed an interest in visiting Kisecik in the Amanus Mountains to some of my workmen, one of whom had a brother in law from the area. I was met with incredulity and told not to go there without someone local because the people in the mountains were "different" and "violent".
[6] The silver mountain and its gate are generally understood to refer to Bolkardağ and the Cilician Gates of the south-central Taurus.

use of specific toponyms – note the specific association of the Amanus/south-central Taurus with silver – may reflect an association of these locations with the characteristics described. As is apparent, for Mesopotamian society the populations dwelling there were inhuman and fierce.

Moving from the realm of myth and legend, the *ḫabirū* and *kaška* represent two LBA examples of groups that typically occupied highland zones in the Levant and Anatolia.[7] Although we can not posit a specific association between these groups and metallurgy, they represent a theme of highland-lowland interaction that is ever-present in Anatolian history and corresponds well with Scott's (2009) analysis of highland groups and other marginal landscapes. As stated by the king of Byblos: "All my villages that are in the mountains or along the sea have been joined to the *ḫabirū*. Left to me are Gubla (Byblos) and two towns" (EA 74: 19-21) (Moran, 1992, p. 143). Where lowland centers were able to exert control over highland settlements, these locales were vulnerable and could be taken by (or voluntarily join) non-state actors.

Though not always an explicitly highland phenomenon, the *ḫabirū* were a population of individuals who had fled from state authority occupying the spaces between agricultural settlements along the Levantine coast (Bryce, 2005, pp. 167–168; Moran, 2003; Naʾaman, 1986; Rainey, 2008). There remains some debate on what it precisely meant to be *ḫabirū*, their relationship to the state was complicated, shifting frequently between adversarial and reconciliatory. Described by some as malcontents and misfits, they were known to variously conquer settlements, act as raiders and marauders, join armies as mercenaries, sometimes hire themselves out to lowland populations as laborers and servants, or even re-enter the service of the king (Youngblood, 2005, pp. 134–136).

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[7] Other groups such as the Lukka and Maša fit this mold as well for the Anatolian context (Singer, 1983, p. 208).

The one place where this characterization does not appear to hold true is at Alalakh. Here, some *ḫabirū*[8] seem to have existed in a relatively comfortable relationship with the state, having rejoined settled society. Wiseman (1953, pp. 11–12) also notes that other factions of *ḫabirū* occupied the areas outside the boundaries of larger settlements, being known subjects of the king and available in substantial numbers, based on their presence in the census lists and husbandry registers. In one instance it is shown that the leader of a group of *ḫabirū* had some 1,486 warriors at his disposal. This situation, however, is not entirely surprising when we consider that the king of Alalakh during Level IV (Period 4), Idrimi, is known to have lived among the *ḫabirū* following his flight from Aleppo and used a force of *ḫabirū* troops to conquer the city of Alalakh (Dietrich and Loretz, 1981).

In a similar pattern of peoples inhabiting mountainous metalliferous regions maintaining an oppositional relationship to their lowland neighbors, the *kaška* represent a more complex problem. Until recently, most reserach has characterized this group as a loose confederation of pastoral nomadic tribes occupying the Pontic mountains running parallel to the Black Sea littoral and who posed an ever-present threat to the Hittite state (Bryce, 2005, p. 47, 2002, pp. 17, 114; Glatz and Matthews, 2005; Yakar, 2008). This representation has been primarily based on the Hittite written record which, necessarily, has a biased perspective regarding peoples who refuse to be brought into the fold. As stated in a pre-campaign ritual (KUB 4.1 ii 11-18):

> "But you, the gods of the land of Kaška, have become rebellious. You have expelled the gods of Ḫatti from (their) land, while you have taken their land for yourselves. The Kaškaeans have also become rebellious. You have taken away from the people of Ḫatti their towns, and you have expelle[d] them from (their) fields (and) their vineyards."

[8] Wiseman (1953, pp. 11–12), at the time of writing, appears to have been unaware of or fully rejected the equivalence of SA.GAZ and *ḫabirū*.

Recently, work by Gerçek (2015, pp. 342–346) has questioned this perspective, suggesting that rather than signifying a specific ethnonym or tribal confederation, the term represents a social category in a similar way to *ḫabirū*. As in the latter case, people and towns at the northern fringes of the empire can become *kaška* if they move to break away from the state. Yet, there are also cases of the *kaška* trading peacefully with Hittite settlements and coming to Hattuşa to be placed under oath (Glatz and Matthews, 2005, p. 53). As such, the relationship between the two entities is not one of pure animosity, with elements of geographic and political stance contributing to the definition of an individual as *kaška*.

We know relatively little about *kaška* internal organization, largely because the Hittites themselves seemed to be somewhat bewildered by it. The configurations of Hittite treaties with *kaška* groups do not seem to have followed the typical Hittite treaty structure, showing considerable variability (Gerçek, 2015, p. 83). One of our few insights derives from the Ten-Year Annals of Muršili II (KBo 3.4 iii 73-76), highlighting the typically non-centralized character of *kaška* society (Bryce, 2005, p. 198). In this case, Muršili states: "Then Piḫḫuniya ruled in a manner un-Kaškaean; all at once – as there was in Kaška not a rule of one (i.e., of a single person) – this Piḫḫuniya ruled in the manner of kingship."

Archaeologically there is relatively little to be said of the *kaška*. While excavations and surveys (Glatz and Matthews, 2005; Yakar, 2008) have been conducted in the Black Sea region of Turkey, their coverage has been small and their capacity to identify LBA material culture has been limited at best. This stems from the fact that the formal similarity between the MBA and LBA assemblages of north-central Turkey makes defining the boundary between these periods on the basis of material culture a difficult prospect (Gerçek, 2012, pp. 16–17). While there is often an expectation that a distinct material assemblage should come to the fore representing a distinct *kaška* identity, Scott's (2009) analysis has shown that highland groups often coopt lowland material culture for their own purposes. As a result, distinctions are likely to be more subtle than our view of archaeological cultures would tend to suggest.

Two later episodes continuing this theme, though less clear in specific details, stem from the medieval period in the Amuq Valley concerning the zuṭṭ and jarājima. The former were a marsh dwelling population originating from Sind[9] who experienced several episodes of relocation. For our purposes, the most relevant is the deportation of a group that had staged a rebellion around Basra in the 9th century A.D. and was subsequently sent to the Amuq. This relocation was meant to manage the risk of further uprisings, while also destabilizing the tribal frontier along the Amanus that separated the Byzantine and Muslim administrations. However, such groups often defected, converted to christianity, and began raiding muslim villages (Eger, 2008, pp. 46, 387)[10]. The jarājima (Mardaites) were an indigenous christian population of uncertain heritage dwelling in the Amanus Mountains. This group was known to occassionally enter into agreements with the local administration in Antakya, though only for such time as they considered it beneficial, and they frequently raided against muslim settlements in the valley (Cobb, 2001, pp. 113–114; Eger, 2008, pp. 391–392).

Ranging from the 3rd millennium BC to the 1st millennium AD, I have established a general pattern of mountain dwelling communities situated in fluctuating oppositional and cooperative relationships with neighboring states. landscapes peripheral to centers of sedentary

[9] Corresponding roughly to modern Pakistan.
[10] Eger (2008, p. 387) also makes note that the zuṭṭ often maintained a tribal geneaology that was crucial from group cohesion but equally vague and flexible. I hesitate to stress the point further without more detailed information, but this is a typical feature of the groups discussed by Scott (2009) as well, which helps facilitate fluid shifts in identity as well as the incorporation of outsiders.

societies were not unpopulated zones ripe for state exploitation. Rather, they were settled with groups that often posed a threat to lowland settlements and entered into agreements with lowland power structures as it suited them. Given the location of essentially all local ore deposits within these marginal landscapes, the existence of such populations complicates any narrative that centers lowland society as a primary arbiter of metallurgical resource exploitation. These peoples occupied a position where they could easily hinder or facilitate the access of lowland groups to highland resources.

### *4.1.2 Metallurgical Communities*

While such populations may be discussed as more or less diversified societies practicing a range of subsistence strategies, there is a more limited range of data that deals specifically with groups broadly defined as metallurgical communities. In these cases, metalworking populations are represented across time and space as distinct and sometimes outcast from mainstream society, while also acting as crucial accomplices in the project of civilization. The use of these ethnographic examples highlights the social nature of occupations and emphasizes the view that metallurgists often occupied marginal landscapes, though they can and do periodically take up residence in cities, they often practice forms of religion considered divergent and even heretical by mainstream society, sometimes possess a different language from their neighbors, and have cultural practices that typically fall well outside the norm. Through the creation of specialized occupational groups, these people create wide-ranging social networks that would facilitate acquisition of resources and interaction. I will limit myself here to a handful of examples, mentioning briefly the Mandaeans of southern Iran and Iraq, the Chalybes of Greek history and myth, and the Agaria of the north-central Indian plateau.

The Mandaeans (otherwise known as the Sabbi or Sobbi) are a Christian community originally based around silver and iron metallurgy residing in the marsh ecosystems at the head of the Persian Gulf. Their religious practice is generally characterized as a form of gnostic Christianity with significant input from John the Baptist. Despite their broad identification as christians[11], there is some polemical characterization of Jesus Christ as a heretic for ignoring rules of ritual purity and making the practice of religion too easy (Drower, 1937, p. 3). Their language is a part of the eastern branch of aramaic languages with a written form that has remained almost unchanged since its development in the Parthian period, while the spoken 'ratna' is a neo-Aramaic reflex of the liturgical language, still spoken in limited circles to this day – notably among silversmiths (Häberl, 2009, pp. 31–32). In terms of their degree of interaction with outside groups, this is typically limited to business interactions since, upon marriage with an outsider, one effectively leaves the group (Drower, 1937, p. 1; Häberl, 2009, pp. 18–19).

In the present they are better known for their silversmithing and the use of a particular form of inlaying silver that remains secret to this day (Drower, 1937, p. 51; Häberl, 2009, pp. 288–289; Wulff, 1971, p. 35). While there is not a history of animosity on the part of the Mandaeans toward their neighbors, it is clear that this group has held itself apart from neighboring societies through linguistic and religious practice and at times been subject to persecution by majority religions. Finally, the preferential preservation of Neo-Mandaic in the silversmiths profession represents an example of a distinct language being preserved as a method of safeguarding occupational knowledge.

[11] There is some debate on this where they are considered in some circles to be non-Christian gnostics.

Linked to this question of language is the issue of Mandaean folklore. Though many studies focusing on the Mandaeans give primacy to their religious practice and the preservation of their liturgical and spoken language, their collection of myths and legends show a particular interest in metals.[12] Among other concepts, we have the notion of the 'worlds of darkness' below the material worlds which are composed of copper, iron, tin, steel, and silver[13]. In this respect, it is also worth noting that the lowest world is of copper while the highest is silver, which may have some bearing on why the Mandaeans seem to primarily work in this material as opposed to others[14]. In another myth recounting a relocation of the Mandai[15] to a new land, upon reaching a new stage of their journey, up to which they had been accompanied by a serpent of steel[16], they found themselves faced by a lion and scorpion of gold and a hornet of an unknown red metal (Drower, 1937, p. 320). Not only are these metals symbolic of particular levels of the world of darkness, but the animals themselves are familiars of what might loosely be termed deities of the world of darkness (Drower, 1937, p. 269). Beyond folklore, metals – gold and silver in particular – also play a significant role in rituals of purity and death, often symbolizing the sun and moon and various qualities such as nobility (Drower, 1937, p. 366).

In the case of the Chalybes, we straddle a fine line between history and myth. There remains an active argument as to the reality of this group, with some scholars locating them around modern Trabzon on the Black Sea coast of Turkey, place them into a category that is

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[12] Interestingly, a comparison may be drawn between ancient Mesopotamian associations of metals with deities vis-à-vis James and van der Sluijs (2008, p. 66)

[13] Or, alternatively – copper, iron, brass, steel, gold, silver, dust.

[14] Blacksmithing being an exception as noted above, although this is a very poorly documented aspect of their economy and so we cannot be sure of its prevalence.

[15] Self-appellation of the Mandaeans.

[16] "…such steel as was made in the ancient times, strongly tempered so that it cut iron as though it were a cucumber." (Drower, 1937, p. 320)

generally mythical, but based around real populations. That they may have been a real population in some sense is supported primarily by the fact that Xenophon and Strabo both claim to have actually found them (Bittarello, 2016, pp. 524–525). Real or not, this group constitutes a metallurgical community extraordinaire, and descriptions of them likely reflect Late Antique views of metallurgical communities more broadly. The common thread surrounding writings on the Chalybes is that they were the inventors of iron (and sometimes bronze) metallurgy, and the iron they produced had special qualities such as being impervious to rust. They resided in agriculturally unproductive montane landscapes covered with trees, and generally subsisted on foraged foods and meat derived from hunting and animal husbandry. They do not eat bread – a typical symbol of civilization in the Near East and Eastern Mediterranean – and they are uniformly hostile to outsiders.

Though this fits my above characterization of metallurgical communities to a great extent, the Greek mythological corpus does provide other examples of ur-metallurgists such as the Cyclops, Dactyloi, Telchines, as well as the metallurgist-god Hephaestus. In the first three cases, there is little to contradict the representation of metallurgical groups as outside the pale of mainstream society, with all being more or less malicious daimones. Hephaestus represents the one example of an apparently "rehabilitated" metallurgist who has entered into a more normalized social milieu. Here, however, we are dealing with not just an individual (as opposed to a group characterization), but a god. By contrast, the Chalybes are explicitly considered a race of men, placed alongside the Amazons as an inversion of the Greek conception of society (Bittarello, 2016, p. 507). As such, we should perhaps see Hephaestus as an exceptional characterization of metalworkers who join proper Greek society, while the broader characterization of metallurgists as a group – whether they are man or daimone – falls well outside the pale of accepted society, occupying the conceptual ends of the earth and acting in a hostile manner toward the civilized world.

The Agaria, an indisputably a real population with a well-defined society, occupy an interesting conceptual space incorporating the realm of myth. They can most accurately be described as an ethno-occupational population centered around the mining, smelting, and working of iron. While there is an argument to be made for the importance of metals to the Mandaean culture at a symbolic and practical level as discussed above, their society and beliefs are not necessarily dominated by them. Among the Agaria the production and working of iron is a defining aspect of the culture. Not being Hindu, the Agaria worship what Elwin (1942, p. 2) consistently refers to as tribal 'demons,' with emphasis on Lohasur, demon of the smelting furnace; Koelasur, demon of charcoal; and Agyasur, demon of fire. There is a substantial mythology surrounding these beings that places them as the mortal enemies of the Hindu gods and recounts numerous conflicts between the two[17] (Elwin, 1942, pp. 19–24). Beyond the mythological opposition between the Agaria and their Hindu neighbors, there are substantial points of contention in the practice of daily life. Among other things is the simple fact that some Agaria eat beef and cover their bellows with cow hides, which immediately places them at odds with their neighbors (Elwin, 1942, pp. 2, 58–59). As a final point, while the Agaria do not typically reside in marginal landscapes as in our other two examples, nor do they permanently inhabit a particular location, leaving them in a socially liminal position (Elwin, 1942, p. 179).

[17] There is significant variation in these mythologies and even the derivations of names used in myths and those used to describe the Agaria, which goes beyond the space available here. Elwin (1942, pp. 26–28) provides an extended quotation that summarizes much of the debate. Much of it, however, centers on whether ironworking populations mentioned in myth and legend as *Asura* can be linked to the modern Asura-Agaria.

Aside from the realm of myth and religion, the working of iron plays a substantial role in the song of the Agaria, providing us with a glimpse into some gendered aspects of the organization of labor (Elwin, 1942, pp. 169–173, 183). In one genre of music we see descriptions of the work process, typically based around a team of three – two men and a woman. While the woman works the bellows "dancing before the furnace," the men charge the furnace and work the iron. In other songs, we hear of the materials used to make the furnace, the charcoal, and the iron. Even in an apparent love song, the success of courtship is based on a young man's capacity to become a smith.

Technologically speaking, while there is some variation from region to region in the appearance of the Agaria furnaces, the general contours of the assemblage and materials used are consistent. In terms of the ores employed, they seek out haematite in association with heavily weathered lateritic rocks, ignoring massive haematites and other ores that would be considered more exploitable by modern standards (Elwin, 1942, p. 176). Following the account of Elwin, the furnaces are typically large cylindrical structures with dimensions approximating 0.75m tall, 2.5m wide at the base, and 1.5m wide at the top. More recent ethnographic work gives dimensions of 60mm at the base and 35mm at the top[18] (Keen, 2013). There is then a much smaller opening in the top, approximately 15cm wide, for feeding the furnace, while at the base there are two openings – one for collecting slag and the other for iron (Elwin, 1942, pp. 181–182). The position of these openings varies from group to group, sometimes being at the back of the furnace and other times being located at the side. There is then a slide built from bamboo and covered in clay extending from the top of the furnace toward the rear that is used for holding ore

[18] The original text gives the measurements in millimeters; however, they should probably be read in centimeters in this case.

and charcoal (Elwin, 1942, p. 181; Keen, 2013, p. 100). Though made from wood, the bellows used by the Agaria are strikingly similar to the ceramic pot bellows known from the Near East, and illustrated in the tomb of Rekhmire (Davey, 1979; Elwin, 1942, p. 186; Keen, 2013, p. 100). Two of these are attached to the furnace by bamboo tubes, while the major variation from group to group is whether they fasten them to the ground with a wooden stake or a large stone[19] (Elwin, 1942, pp. 182–186).

## 4.2 Conclusion

I have attempted here to present two points that are relevant to the discussion of metal production in the Near East generally, and in Anatolia in particular. The first of these has centered around an acknowledgement that the mountains hosting many of the region's ore deposits were occupied in the ancient period by populations intertwined in complex relationships with neighboring lowland communities. The features characterizing these relationships proved durable not only over a long period of time in the local context, but have been shown to characterize highland-lowland relationships more generally. In light of this, it cannot be assumed that lowland states had unfettered access to metal resources, and this may have played a role in their economic calculus when constructing networks to supply their own secondary metallurgical industries. The second point has been that communities engaged in metalworking often constitute distinct social (if not specifically ethnic) groups that typically originated from marginal landscapes, with unique religions, ethnicities, social practices, and technological styles. Even if individuals and their family units no longer resided in the marginal landscapes they

[19] As Elwin (1942, p. 184) notes "So important is this distinction that there can be no intermarriage between those who use a peg and those who use a stone, no inter-dining, and they will not share one another's pipes."

hailed from, it is probable that the social bonds uniting them continued to shape and facilitate their access to and use of resources. If the individuals living and working in the Area 4 workshop at Tell Atchana were part of such a group, their particular knowledge of Taurid ores and methods of bronze production, as well as social ties with communities still in the highlands would have facilitated their travels or served as a procurement network for the materials they worked with.

In the following chapter, I will turn to state-centered metalworking first to examine two examples that are typically considered as paradigmatic in Near Eastern archaeology, followed by a review of the Anatolian evidence and how it reflects on these cases. I will then examine the textual records of the Hittites, Ebla, and Tell Atchana. The choice of the Hittite and Eblaite texts as my primary sources is based primarily on the quality of data to be derived from each, but also the fact that they reflect two systems that Alalakh was situated between spatially, temporally, and culturally. In this discussion, it will become clear not only that society at Alalakh was in some ways quite distinct from neighboring cultures, but when considered in light of the evidence presented in this study, the system represented in the texts appears to have only had a tenuous link to the broader sphere of action represented in the archaeological record.

# 5 Production and Consumption of Metals in the East Mediterranean

In the preceding chapter, I introduced material concerning highland and metallurgical communities and some issues surrounding their impact on the accessibility of ore resources. Exerting a substantial influence on the resource-procurement segment of technological systems centered on highland resources, these issues represent important considerations in the first step of the metallurgical *chaîne opératoire*. Here, I will begin with a brief detour to mention staple and wealth finance and its articulation with Late Bronze Age political economy to orient the reader to the political scene that Alalakh inhabited during the period of interest and the underlying reasons for the importance of metals in this political system. Given the emphasis on diachronic contextualization in systems narratives of technology, I will take a step back and introduce the contours of development of primary production in the Eastern Mediterranean over the course of the later Chalcolithic and Bronze Age. Data on this segment of the broader *chaîne opératoire* is almost entirely archaeological, although some textual material of relevance from MBA Anatolia will be introduced where appropriate. Finally, because textual data often provides some of our most direct information on patterns of labor organization, metal use, and consumption, often discussing objects and practices not preserved in the archaeological record, I will end the chapter with textual material stemming primarily from Hittite contexts and Ebla, with additional supporting information from Mari, Ugarit, and Mesopotamia. Taken together, these data constitute the macro view of several Eastern Mediterranean metallurgical technological systems as we currently understand them, including their physical distribution, infrastructure, management, and social integration.

The world of the Late Bronze Age Near East (1650 – 1200 BC) is typically understood as a period of human history that witnesses a greater articulation of concepts of international diplomacy and the coalescence of several large territorial empires. Helping to drive these developments are at least two significant innovations. The first was the rapid adoption of writing during the mid-3rd to early 2nd millennia across an expanding swath of the Near East, not just for local record keeping and administrative duties, but also for long-distance communication (Liverani, 2001, p. 2). The acceptance of Akkadian as a written *lingua franca* for this communication and the creation of an international language of diplomacy centered on the expression of hierarchical relationships as symbolic (and sometimes literal) familial relationships, was crucial (Liverani, 2001, pp. 128, 135). This codification of regional power hierarchies as family relationships, officially supported through written treaties, generated the foundation for creating extensive networks of vassal states and allies over distances of more than a few days travel from a politically dominant settlement. A material corollary to this was the development of widely dispersed standardized ceramic assemblages, variously interpreted as an indicator of state-sponsored standardization or long-distance connectivity (Costin and Hagstrum, 1995; Glatz, 2009; Pucci, 2019; Rice et al., 1981, p. 220; but see; Stein and Blackman, 1993), and the coordinated long-distance exchange of particular types of material culture and raw materials as part of the theatre of these imagined (and sometimes real) kinship relationships (Schachner, 2009).

As these political networks developed, staple and wealth-finance systems were continually adapted as increasingly distinct methods for the support of long and short distance economic networks. In our conception of these models, finance refers to strategies of resource management to facilitate social structuring intended to maximize access to labor and natural resources (D'Altroy and Earle, 1985, p. 187). Under the guise of staple-finance, alimentary goods and general necessities such as textiles constitute the fundamental unit of value in the economic and taxation system, as seen in examples ranging from the early Mesopotamian city states to localized economic systems of Iron Age Anatolia (Archi, 1988a; Baines and Yoffee, 1998; Brumfiel and Earle, 1987; Castellano, 2018; D'Altroy and Earle, 1985). The state typically collected a portion of the produce grown by the general citizenry or had them work state-owned fields as tax, with the proceeds then being distributed to a range of state personnel and attached specialists as payment. With sufficient food surpluses to support this portion of the population, technological advance and the development of increasingly complex society is assumed to follow. As noted by D'Altroy and Earle (1985, p. 188), though these systems are efficient in distributing basic necessities, the bulk and weight of the goods involved means that they quickly become cumbersome for long-distance or high-value exchange, especially in circumstances where transportation is primarily overland (Brumfiel and Earle, 1987, p. 6; Scott, 2017, p. 41).

As prestige goods and long-distance trade became increasingly prominent components of ancient societies for signaling status differentiation, systems based on wealth-finance began to develop alongside those based on staple-finance to facilitate these interactions (Brumfiel and Earle, 1987; D'Altroy and Earle, 1985; Earle et al., 2015). In this setting, value is embodied in special materials (i.e. metals and precious stones) or value-added goods, which the state is often able to monopolize either through control of long-distance exchange or controlling access to resources (Brumfiel and Earle, 1987; Earle et al., 2015; Knapp, 2008, p. 377). These materials are then assigned a value in reference to other goods in circulation, facilitating their use for payment and exchange (i.e. Heltzer, 1977; Stieglitz, 1979). A prime example of this phenomenon appears in the MBA textual archives from Kültepe in central Turkey, documenting an extensive trade in tin, textiles, copper, and silver where incoming goods were required to first pass through palace, giving the administration first choice in all acquisitions (Barjamovic, 2011, p. 13; Dercksen, 1996; Larsen, 1976; Michel, 2008, pp. 75–76; Veenhof and Eidem, 2008, pp. 83–86). Through the establishment of monopoly control over such resources, the state is able to deprive peripheral areas of an independent financial base granting them access to a broader economy, thereby decreasing the risk of rebellion and facilitating integration of areas distant from the state core (Brumfiel and Earle, 1987, p. 6). The expansion of systems of exchange based on metal as a store of value (Frangipane, 2018; Lehner, 2015, p. 81; Peyronel, 2010) provided a foundation for the elaboration of commercial networks as well as a means by which wealth could be efficiently transferred between politically dominant and subservient locales.

While the broad scale trends in social, political, and economic development in the ancient Near East outlined above are broadly accepted, the characterization of metallurgical industries as part of the support structure for increasing complexity has focused on Cyprus and the southern Levant (Timna and Faynan) as paradigmatic (Hauptmann, 2011, p. 189). In both cases, it is postulated that state management facilitated the development of large-scale smelting industries that supplied interregional trade networks and major state industries (Avner, 2014, pp. 103–104; Ilan and Sebbane, 1989; Knapp, 2012, pp. 17–18). In turn, it has been suggested that state-sponsored increases in the scale of smelting activity and associated technologies may have also lead to the development of reliable iron smelting (Erb-Satullo, 2019, pp. 18–23). However, both cases fall far outside the norm of the Near Eastern milieu in terms of the landscapes represented, the geographic concentration of ore resources, and the social environments represented.

For the Levant, deposits of copper oxide ores are concentrated at Faynan and Timna in the Wadi Arabah (see below). Though the wadi is geographically isolated to a certain extent, bounded by the Negev Desert and Jordanian Plateau on the west and east, the segment of the valley hosting Faynan is amenable to agricultural exploitation with plentiful, if not unpredictable water resources (Ben-Yosef, 2012; Hauptmann, 2007, pp. 39–49). The scale of ancient settlement in the Arabah is illustrative of its capacity to support large population centers, particularly when one considers sites such as Jericho (Hauptmann, 2007, p. 47). Adams (2002), meanwhile, has noted the extent to which the Faynan sites represent a continuation of Levantine settlement hierarchies, tying it securely into the surrounding cultural milieu. Though its ore resources are highly localized, the significantly harsher environmental circumstances of Timna present challenges for permanent settlement and exploitation (Ben-Yosef, 2012). As will be discussed below, its involvement in state managed industries has come under serious reconsideration.

According to Knapp's (2008) study of pre- and proto-historic Cyprus, island landscapes represent a paradox between isolation and connectivity. On the one hand, there is the obvious physical separation and capacity for mediated interaction that the surrounding sea affords, as well as the fact that various technological and social systems related to thalassic life facilitate the creation of specific islander identities (Knapp, 2008, pp. 19–30). Such factors may have been instrumental in the social integration of the island and the potential establishment of centralized control over local industries (Knapp, 2008, p. 337). Meanwhile, the bodies of water that hold islands apart from the mainland also facilitate communication and transportation, meaning that islands and islanders are often essential components of long-distance exchange networks. Considering the rich ore deposits and ample fuel resources on Cyprus, the cultural cohesiveness of many island cultures, and the logistical benefits conferred by easy access to a large body of water, Cyprus represented a perfect confluence of factors for the creation of a large-scale smelting industry, the existence of which is evidenced by the tons of ingots recovered from the Uluburun and Cape Gelidonya shipwrecks (Gale, 2011; Hauptmann et al., 2002a; Kassianidou, 2009; Pulak, 2000).

Based on archaeological material, both regions were important copper producing zones during the Bronze Age, while a variety of textual and analytical data has been used to support a contested association of Cyprus with the region of *Alašiya*, which is frequently mentioned as a major copper supplier (Ben-Yosef et al., 2010; Gilbert, 2017; Hauptmann, 2007; Kassianidou and Knapp, 2005; Knapp and Kassianidou, 2008; Merrillees, 2011; Weisgerber, 2006). Whether one accepts the equation of Cyprus with *Alašiya* or not, the paradigmatic status of Cyprus, Faynan, and Timna in the archaeological and historical literature is pervasive. Yet, the uniqueness of the circumstances that facilitated their development make their use as paradigms flawed. If the textual record mentions tons of copper from a specific source being shipped between kings as part of an elaborate political economy of the elite (Knapp, 1990), it does not automatically follow that the source of that metal was the primary supplier for the entire eastern Mediterranean.

To study these phenomena, we typically deal with two sets of data that very rarely speak to one another directly (cf. Peyronel, 2010). First, the written record, consisting of tablets that chronicle the conduct of diplomacy and its attendant modes of gift exchange, enumerate types and quantities of tax income, record available population, and provide us with rare glimpses into the conceptual world of ancient peoples. Second, the archaeological record, the remains of human action as opposed to textual claims of action. As has been frequently noted in previous scholarship, texts were compiled by a very specific subset of the population with very particular goals in mind. This means that texts may be deliberately misleading and are almost certainly a very partial picture of the full scope of activity taking place in terms of both the people involved and the relevant aspects of their labor. Returning to the Kültepe texts as an example, these record only the activities of Assyrian merchants while ignoring much of the activity of local Anatolians (Dercksen, 1996; Larsen, 1976; Veenhof and Eidem, 2008, p. 86).[1] Such oversights allow us to conflate importance with primacy, as discussed above. Nevertheless, because they were written by rulers, elites, and merchants who controlled and traded between urban centers, such texts have much to tell us about large-scale lowland societies. The archaeological record is arguably a more representative, albeit fragmentary and equivocal, dataset having been created by the actions of groups and individuals at all societal levels. Unlike texts, it has no direct capacity to tell us about motivations or the circumstances of action, leaving us to infer motives based on patterns in the archaeological and landscape record. Under these conditions, the available material merely affords archaeologists certain avenues of interpretation, and the point of data collection and subsequent analysis is to constrain the range of possible interpretations (Killick, 2001, p. 483; Schiffer, 2011, pp. 5–7).

The discussion of wealth finance systems and the particularity of the circumstances that structured metal production at Faynan and on Cyprus emphasize two points relevant to the discussions in chapters 2 and 4. First, resource procurement and its configuration in the landscape is strongly shaped by the relationship between populations in settlements, their hinterlands, and in outlying resource zones. Second, when possible and profitable, state entities often attempt to exert control over production and procurement systems. In terms of

[1] Regarding specifically technical processes, Oppenheim's (1970) study on 2nd millennium Mesopotamian glass texts and Rehren and Martinon-Torres (2008, pp. 175–185) discussion of medieval brass production both provide examples of scribes and scholars recording highly incomplete accounts of the processes they are studying.

technological style and craft specialization, this is thought to manifest as routinization, standardization, and sometimes centralization of production processes. In the following pages, archaeological and textual data frame interpretive possibilities based on these two principals from the broader Near Eastern context. The addition of analytical data in later chapters details how production was organized, how the productive system seems to have interfaced with the palace, and the general outline of resource procurement networks at Tell Atchana.

Through a review of bronze age metallurgical industries as seen in the archaeological records of Cyprus, the southern Levant, and Anatolia I will highlight the substantial regional variability that characterizes the metallurgical systems of these regions. Tapping into the discussion from chapter 4, this will help to show the reliance of metallurgical industries on relationships with marginal landscapes and communities. Finally, I will introduce textual material concerning metals, their taxation and trade, and metalworkers from the Hittite, Eblaite, and Ugaritic sources, followed by a more detailed treatment of LBA Alalakhian records. This discussion will present data reflective of elite concerns surrounding metal, the inclusion of metals in wealth finance systems, and the position (and procurement) of metalworkers in Near Eastern societies. By considering these datasets in concert, I will show that configurations of metallurgical systems are the result of relationships conducted across a topographically complex landscape that often-confounded efforts by lowland states to control metallurgical production, except in exceptional circumstances.

## 5.1 Metallurgical Industries of the Bronze Age Eastern Mediterranean

Characterization of metals and metallurgical industries in the Near East from the terminal stages of the 4th to the beginning of the 1st millennia BC have emphasized causal relationships between the development of urbanism and complex society on the one hand, and craft specialization and complex technology on the other.[2] In the eastern Mediterranean, much of the evidence for this position is drawn from Chalcolithic, Early Bronze, and Late Bronze Age levels at the sites of Timna and Faynan (Adams, 2002; Avner et al., 2018; Hauptmann, 2007; Ilan and Sebbane, 1989; Levy et al., 2002; Levy and Shalev, 1989; Thornton, 2009; Thornton and Roberts, 2014; Weisgerber, 2006). More closely related to the establishment of long-distance trade and international diplomacy, a similar narrative prevails regarding the development of metallurgy on Cyprus during the Late Bronze Age, however, due to ambiguity in the archaeological record resulting from modern destruction of evidence for ancient mining and metallurgy, the associated claims tend to be less specific (Kassianidou, 2008; Kassianidou and Knapp, 2005; Knapp, 2012). Meanwhile, a vast body of research from Anatolia highlights the range of variation to be seen in the development of metallurgical industries and the extent to which they defy simple classification (Frangipane et al., 2001; Hauptmann et al., 2002b; Lehner et al., 2015; Lehner and Schachner, 2017; Mehofer, 2016, 2014; Seeliger et al., 1985; Thornton, 2009; Wagner et al., 2003, 1986; Yener, 2000; Yener and Vandiver, 1993).

[2] A particularly clear-cut example of this perspective can be seen in Maxwell-Hyslop's (1960) discussion of jewellery from Ur.

### *5.1.1 Levant*

Although the precise chronologies of exploitation at Timna and Faynan vary, they share a relatively similar overall trajectory, which has resulted in the definition of what Thornton has termed the "Levantine Paradigm" (Thornton, 2009). According to this view the exploitation of copper ores in the region began during the Neolithic with the production of beads, pendants, and cosmetics (Hauptmann, 2007, pp. 257–261). This was succeeded by the development of two parallel traditions during the Chalcolithic and Early Bronze I, with one focused on the utilization of local copper ores for the production of pure copper, while the other involved the use of Cu-As-Sb alloys for the production of precocious array of prestige goods (Golden, 2009, p. 285). In the former tradition, ores from Faynan were typically mined and transported to habitation sites in the Beersheva Valley for smelting and working into utilitarian goods (Hauptmann, 2007, p. 291; but see, Golden, 2009, p. 295). The latter tradition, defined primarily by the Nahal Mishmar hoard, as well as Abu Matar and Shiqmim, shows the production of prestige goods with a uniformly non-utilitarian character using materials that originated from well outside the Arabah (Golden, 2009, p. 290; Hauptmann, 2007, p. 294; Tadmor et al., 1995). The highly localized appearance of metals among Beersheva sites during the Chalcolithic led to the general hypothesis that this region exercised a monopoly over copper production and resources in the southern Levant (Burton and Levy, 2011, pp. 186–187; Hauptmann, 2007, pp. 261–265, 289; Levy and Shalev, 1989, p. 366), while others have gone a step further, suggesting that the smelting of metals in settlements was carried out by a developing social elite determined to prevent others from gaining their esoteric knowledge (Levy, 1998).

With the transition from the Early Bronze I to the Early Bronze II, the Beersheva sites lost their apparent control over metal resources in the southern Levant, complex Cu-As-Sb alloys cease to appear within the assemblage, and local production of copper relocates wholesale to the mines at Faynan (Avner et al., 2018; Genz, 2000, p. 57). The span of the EBII-IV represents the first period of industrializing metallurgy in the region, with an estimated 5000 tons of slag being attributed to this phase of production, representing several tons of copper metal (Levy et al., 2002, p. 427). This development, coinciding with the earliest urbanized and fortified settlements in the region such as Arad, Bab edh-Dhra, and Jericho has often been taken as a catalyst for the initial urbanization of the Levant, where urban elites sat atop a developed urban-rural division of labor and controlled production and distribution of copper goods (Milevski, 2013; Stöllner, 2003).

An assessment of distribution data on metals and the types of products in circulation contradicts this perspective. As Genz (2000) has noted in his evaluation of the Early Bronze Age in the region, none of these larger sites show any particular attachment to metalworking, be it primary or secondary (Genz and Hauptmann, 2002; Hauptmann, 2007, p. 272). While Arad has typically been held up as a major node in the exchange of metals in the southern Levant, most of the objects found there were small tools such as awls. In fact, the only major metalworking site for the Early Bronze age is that of Khirbet Hamra Ifdan, located in the immediate vicinity of Faynan, yielding hundreds of molds, crucibles, furnace fragments, and copper prills (Levy et al., 2002). Meanwhile, the fact that the vast majority of metals known from the southern Levant for this period are utilitarian goods undermines any particular link to elite spheres (Genz, 2000) and may even be taken to undermine the status of copper as a prestige good in this context (contra Hauptmann 2007, 274).

The basis for suggesting control over metal production and trade by urban elites is founded on the view that only complex hierarchical social systems would have been able to organize the logistics of mine operation and final distribution of metal goods (Stöllner, 2003). In this scenario, if nomadic or semi-nomadic populations are considered at all, it is as part-time labor in the service of urban populations. This need not be the case, as Genz (2000) and Avner (2014) have convincingly argued, local dwelling nomadic or semi-nomadic populations would have actually been in a better position to handle just about every aspect of mine organization from food provision to transport at Faynan and Timna (see also; Hauptmann 2007, 293). Indeed, if urban dwellers sought to exploit resources in these areas, they may well have been the junior partner in the arrangement, requesting permission from local nomad groups.

Following a decrease in production activity at Faynan and Timna during the MBA, there is a strong resurgence in the LBA, primarily at Timna (Avner, 2014; Ben-Yosef, 2018; Weisgerber, 2006). Since the 1969 discovery of what was initially identified as an Egyptian mining temple, Timna has been treated as a clear-cut illustration of the primacy of state actors in the organization of mining and smelting operations (Rothenberg, 1996). A re-evaluation of the stratigraphy of the temple, a technological-style based interpretation of the evidence, and a series of new radiocarbon dates have called this narrative into question (Avner, 2014; Avner et al., 2018). It now appears that the Egyptian elements of the structure were not only pre-dated by an indigenous shrine of standing stones (*masseboth*), but the later Egyptian elements were installed in a subordinate position to the original shrine with both being used contemporaneously. After the Egyptians had left, elements of their shrine were co-opted into the still active local structure. Looking at the evidence for mining, a single image of a mine showing protruding stairs was used to suggest that the Timna shafts were of Egyptian construction, however, the method drawn and the method used differ completely, while local parallels constructed as dwellings in the EBA at Abu Matar are consistent with the Timna examples (but see; Weisgerber 2006, 13). A similar argument is applied to the smelting furnaces as well, with the cylindrical furnaces of Timna differing from the rectangular Egyptian battery furnaces of the Sinai Peninsula. Perhaps of greatest significance are new C14 dates which have shown that several furnaces ascribed to the Egyptian period were in fact Islamic in date, while others pre-date the Egyptian arrival by around a century. In conjunction with dates showing earlier exploitation during the Middle Bronze II and later during the Iron Age, this shows that the method in practice at Timna had little to do with the Egyptians as a direct intervention, and suggests that their presence was probably as an important customer (Avner, 2014, p. 142).[3] Finally, recent investigations of the extensive metallurgical workshops at Pi-Ramesses suggest that while some Timna copper may have been in circulation in the LBA Egyptian metallurgical industry, its influence was apparently limited (Rademakers et al., 2017). From the data presented, it appears that while foreign copper had a minor impact in the overall assemblage at Pi-Ramesses, a major proportion represents mixing of locally focused Sinai and Eastern Desert sources (Rademakers et al., 2017, fig. 7).

One potential solution to this conundrum stems from the site of Ugarit, located about 70 km south of Tell Atchana, in the northern Levant. Though this site has no natural metal resources, it has long been suggested that it served as a major trans-shipment point in Mediterranean trade networks by virtue of its strategic location, with further access to inland networks (McGeough, 2007, p. 61). Though its role in international trade continues to be debated (McGeough, 2007, pp. 201–202), the material evidence from the site suggests substantial metalworking activities including crucibles, bellows, slag, matte, as well as oxhide ingot fragments, an oxhide ingot mold, and ingots of silver and lead. Nevertheless, the great bulk of

[3] Avner's discussion (*ibid.*) of ceramic assemblages of the site is also striking in showing essentially no Egyptian presence, highlighting the local character of the industry.

the LBA metallurgical material from the site remains unpublished, making the creation of a coherent narrative difficult (Dardaillon, 2012; Philip, 1988, p. 195). Taking the volume (if not the quality) of evidence from Ugarit as an indication of its involvement in the metals trade, if we abandon assumptions that state actors controlled copper resources, then a scenario in which Anatolian copper was being shipped through Ugarit to Egypt need not take political considerations into account at all.

### *5.1.2 Cyprus*

The organization and timeline of the Cypriot metals industry during the Bronze Age is a matter of ongoing debate, unclear in its beginnings or trajectory until the Late Bronze Age (Kassianidou, 2008; Peltenburg, 2011; Webb et al., 2006). Due to modern industrial disturbance of archaeological remains on the island, the most substantial evidence for its significant role in the LBA metals trade are textual records (Knapp, 2011, p. 2011, 1990; Muhly, 1989)[4] and shipwrecks along the coast of Turkey illustrating the export of oxhide ingots linked to Cypriot ores through lead isotope analysis (Hauptmann et al., 2002a; Knapp, 1990; Pulak, 2000). Excavations in major settlements along the Cypriot coast, and a lesser number in the Troodos Mountains provide glimpses into the productive mechanisms that made the LBA industry possible (Kassianidou and Knapp, 2005; Knapp et al., 2001; Knapp and Kassianidou, 2008). As a result of this evidence, it has frequently been suggested that "copper oxide ingots and, to a lesser extent, bun-shaped ingots made up the overwhelming bulk of metal that was traded "world-wide" during the Late Bronze Age" (Hauptmann et al., 2002a, p. 2) and that "sometime after the beginning of the second millennium BC Cyprus begins to produce and export

[4] But see; (Gilbert, 2017; Merrillees, 2011) for views contradicting the identification of *Alašiya* with Cyprus.

significant amounts of copper and eventually takes over as the main source for this metal for all of the Eastern Mediterranean" (Kassianidou, 2013, p. 38).

While it appears all but indisputable that Cyprus seems to have been the largest copper producer in volume during the second half of the second millennium BC – at the risk of making a negative argument, most provenance evidence to-date suggests that while the geographic dispersal of Cypriot metal was quite wide (Lo Schiavo, 2009), its net distribution was relatively limited. Although there are examples of oxhide ingots, mainly produced in Cyprus (Gale, 2011, p. 215), as far afield as Sardinia, Mesopotamia, Bulgaria, and even Germany (Hauptmann et al., 2002a), these are typically isolated finds. Meanwhile, evidence for the actual use of this metal is rare and often equivocal  (Begemann et al., 2003; Gale et al., 1985b; Gale and Stos-Gale, 2007; Johnson et al., 2020; Pernicka, 1987; Philip et al., 2003, p. 87; Rademakers et al., 2017; Sayre et al., 2001; Soles, 2004, p. 58; Stos-Gale et al., 1995, 1997). This may suggest that most Cypriot copper was destined for use in strictly circumscribed networks[5] and would represent an example of one of the few contexts where a state entity exercised significant control over primary production.

During the first half of the 2$^{nd}$ millennium BC, the first notable indications of a developed local metallurgical industry began to emerge on the island. At sites such as Ambelikou Aletri (Webb, 2015; Webb and Frankel, 2013), Alambra (Gale et al., 1996), and Pyrgos Mavroraki (Kassianidou, 2008, p. 254) evidence for mining and processing as well as smelting has been excavated (Kassianidou, 2008). In the case of the former, located near what was once one of the largest copper deposits on Cyprus, there was small a camp with strong indications of mining and

[5] See, for example, Rehren and Pusch (2012, p. 218) for their hypothesis on "Special Project Copper"

secondary metallurgy. However, there is nothing in the analyzed metallurgical assemblage to suggest primary smelting, though this obviously cannot be excluded (Georgakopoulou and Rehren, 2013). Indeed, in a detailed characterization of the ground stone tools excavated there by Webb (2015) has been able to provide evidence supporting a spatial separation between ore processing and domestic contexts, meaning that they may have simply missed the relevant location. On the southern side of the island, the site of Pyrgos yielded a variety of evidence for smelting, representing the largest slag assemblage for this period on Cyprus. Nevertheless, the slag suggests a relatively inefficient process and the scale of production is difficult to assess without precise information on the quantities of collected (Kassianidou, 2008). What this incomplete picture suggests are a variety of different systems of organization and production in play, from settlement-based metallurgy including primary and secondary production alongside a variety of other activities as at Alambra and Pyrgos, to more specialized forms of exploitation as seen at Ambelikou.

More secure, albeit still complex, evidence has originated from cities along the coast of Cyprus. Sites such as Enkomi, Kition, and Hala-Sultan Tekke (Karageorghis and Kassianidou, 1999; Kassianidou, 2016, 2012, 2008; Knapp, 2012) have long been identified as major metalworking centers of the LBA, yielding hundreds of kilograms of slag and other debris as large agglomerations. Upon analysis by Hauptmann (2011), it has been convincingly shown that the activities taking place at Kition and Enkomi were a final stage in the primary processing of copper sulfide ores – namely, the final smelting of copper matte. In this context, work at the site of Politiko Phorades (Kassianidou, 2008; Knapp, 2012; Knapp et al., 2001; Knapp and Kassianidou, 2008) has shown the first stage of this process, where matte was produced on an industrial scale leaving some three tons of slag behind. Finally, the site of Apliki Karmallos

(Kassianidou, 2018), the only suggested mining settlement of this period on the island, represents the extractive phase of the industry.

Most debate has centered on the link between these various sites and their connection to the broader metals trade. This issue was further complicated by lead isotope data suggesting that all oxhide ingots produced after 1400 BC were cast using metal originating solely from the Apliki ore deposit (Gale, 2011; Stos-Gale and Gale, 2010) while none of this metal appears to be used elsewhere in Cyprus (Kassianidou, 2009; Knapp, 2012; Papasavvas, 2012). At first this hypothesis generated significant backlash (Kassianidou, 2009, pp. 62–63; Knapp, 2012, p. 22) and although initial reluctance to accept it seems to have subsided in recent years (Kassianidou, 2018), the precise relationship of this mine to settlements such as Enkomi remains in question. In light of the observed patterning of evidence, a likely hypothesis has been that Enkomi was the primary political center of the island and that it had been able to centralize production and authority around itself (Knapp, 2008, p. 133).

In the latter stages of the Late Bronze Age and the beginning of the Early Iron Age, metal production in Cyprus continued at a massive scale. By this point, what political centralization may have existed was heavily fractured, and the industry was now under the control of competing city states (Kassianidou, 2014). As the period progressed, some have suggested that an apparent decline in copper production was the result of competition from resumed smelting activity at Faynan, resulting in the Cypriot metallurgical industry switching to iron production (Muhly and Kassianidou, 2012, p. 125). Among other things, what this type of narrative reflects is the extent to which metallurgy in the eastern Mediterranean is conceived of as a bi-polar system.

### *5.1.3 Anatolia*

In Anatolia there is a far less unified picture than seen in Cyprus or the Levant. Part of this is related to the history of investigation, which has not achieved the same level of coverage seen in the two previous examples. However, this is a function of Anatolia's size, as well as the fact that copper sources of varying extent and richness are present across the region. To accompany this wealth of natural resources, many of these locales show evidence for ancient exploitation (Seeliger et al., 1985; Wagner et al., 2003, 1986; Wagner and Öztunalı, 2000). This fact is both blessing and curse in that, while it provides a vast amount of material to study, it has meant that the degree of investigation has often not been as intensive nor as detailed, hindering our ability to generalize. As a result, the greater geographic dispersal of Anatolian mining and smelting evidence combined with the obscuring of ancient slag heaps and mines through later reworking (i.e. Seeliger et al., 1985, pp. 604–605, 611–612, 621–633) often gives the impression that Anatolian exploitation patterns rarely achieved the scale of the Levantine or Cypriot examples. Although this may be true at the level of individual mining and smelting operations, the distribution of Anatolian metal identified through lead isotope analysis in the Eastern Mediterranean has proven comparable with its larger-scale neighbors (Gale and Stos-Gale, 2007; Stos-Gale and Gale, 2010; Webb et al., 2006). The concentrated nature of the Cypriot and Levantine industries has led to an emphasis on single sources, resulting in attempts to foreground massive deposits such as those at Ergani Maden. This is a top-down perspective on resource management that is at odds with the Anatolian evidence.

As mentioned above, Yener (2000) has provided a thorough synthesis of the early stages of metallurgy in Anatolia up to the end of the Early Bronze Age. Since its publication two decades ago, this work has remained fundamentally current, defining the trajectory of Anatolian metallurgy in general, as well as the contours of early regional traditions in eastern and Mediterranean Turkey in particular. The general impression is one of precocious regional development in the mountainous zones of eastern Turkey during the Chalcolithic, followed by distinct, but highly developed and interconnected traditions in the Early Bronze Age. In particular, the Early Bronze Age appeared to be the earliest period where we have evidence for organized metal production in the form of the settlement and mine at Göltepe-Kestel, where tin was produced on an unprecedented scale (Adriaens et al., 1999; Yener and Vandiver, 1993). That this period coincides with the earliest bronzes in the Near East is unlikely to be a coincidence, although, as we shall see later on in this study, 3rd millennium BC evidence from Tell al-Judaidah and 2nd millennium material from Tepecik (Esin, 1987, p. 71) shows striking parallels with evidence of bronze manufacture at 2nd millennium BC Alalakh, which may point to a regional tradition of bronze production involving the use of polymetallic tin-bearing ores (Adriaens et al., 2002; Braidwood et al., 1951; Braidwood and Braidwood, 1960, p. 314; Yener and Özbal, 1987).

A series of new projects have also begun to shed further light on this stage of increasingly intensive metallurgy. Investigations at Çamlıbel Tarlası push back the dating for specialized mining activity to the Late Chalcolithic-Early Bronze transition, represented by a small intermittent settlement smelting arsenical copper in proximity to the ore source itself (Boscher, 2016; Schoop, 2015, 2011). This reflects an early stage of Yener’s two-tier production model for the Anatolian highlands. Further supporting this model, recent work at the Early Bronze II site of Derekutuğun has similarly yielded evidence for the establishment of processing activities in proximity to ore – and native copper – sources (Yalçın et al., 2015; Yalçın and Maass, 2013). Meanwhile, further to the west, work at the early 3rd millennium BC site of Çukuriçi Höyük has revealed a developed tradition of secondary metalworking with a wealth of molds and finished objects as well as evidence for the involvement of speiss (iron-arsenide) in the production of arsenical copper (Mehofer, 2016, 2014). Finally, adding to the already complex picture of tin sources in the Near East and the development of bronze metallurgy, work at Hisarcık near the ancient site of Kültepe-Kaneš and modern Kayseri has revealed evidence for Early Bronze Age exploitation of a small tin deposit on the skirts of Mount Erciyes (Yener et al., 2015). Nevertheless, the overall sequence of metallurgical development in Anatolia during the Early Bronze Age poses significant challenges in terms of linking assemblages from various sites chronologically, meaning that this body of data is difficult to meaningfully interpret (Lehner et al., 2015, pp. 207–209).

In the Black Sea region, there is extensive evidence for a local tradition of arsenical copper use. This shows primarily in the burial goods of the large cemetery at the site of İkiztepe (Bilgi, 2011; Kunç, 1986), but also in the assemblages of Mahmatlar and Horoztepe (Akok and Koşay, 1950; Esin, 1969; Smith, 1985), the former also showing evidence for silver working, with close similarities to the material from Alaca Höyük. It is likely that this tradition is based upon locally produced metal in as far as the copper deposits located in this region are frequently arsenic-rich and found in association with ores such as arsenopyrite, many occurrences of which are associated with massive slag heaps, though these are often difficult to date (Kaptan, 1988; Özbal et al., 2000). Due to significant difficulties in surface survey and excavation imposed by the mountainous forested terrain of this region our understanding of its prehistoric metallurgical history is rather limited. As such, many of our conclusions are inferred from the massive slag heaps that dot this region, appearing on the order of tens to hundreds of thousands of tons each, likely covering substantial earlier workings, as well as lead isotope data that points toward the use of these deposits in prehistory (Hauptmann et al., 2002b, p. 62; Seeliger et al., 1985, pp. 603–621; Wagner et al., 1989, pp. 645–663).

Further to the east, excavation and field survey provide a more thorough level of coverage, albeit with significant limitations. The most thorough dataset continues to be that compiled by the group out of Heidelberg University (Seeliger et al., 1985; Wagner et al., 1989). According to this data, indications of prehistoric copper mining and smelting were found in Erzurum, while potential gold exploitation was mentioned in Kars (Wagner et al., 1989, pp. 652, 664). To the south, the area around modern Elazığ and Diyarbakır has long represented on focus of archaeometallurgical research in eastern Turkey, particularly as it applied to earlier stages of metallurgical development. One reason is the obvious presence of the copper mine of Ergani Maden as well as a host of smaller deposits in the region (Seeliger et al., 1985, pp. 621–638; Wagner et al., 1989, pp. 664–669) and their association with Neolithic native copper working at Çayönü Tepesi (Maddin et al., 1999). Another reason for this focus is fortuitous (or unfortunate), because the sites of Tepecik, Tülintepe, and Norşuntepe were excavated in this region during the 1960's and 70's as rescue excavations during the construction of the Keban Dam (cf. Burney 1980). Each of these three sites yielded workshops with evidence for the smelting and working of metals during the Chalcolithic and Early Bronze Ages, all revealing the use of complex polymetallic ores (Esin, 1987; Seeliger et al., 1985, pp. 644–648; Yalçın et al., 1993; Yalçın and Yalçın, 2009; Zwicker, 1980). Immediately to the west of the Keban Reservoir, Arslantepe yielded a host of evidence for an exceptionally precocious metalworking tradition based on a similar use of polymetallic ores in a variety of social contexts including "Royal Tombs", palace armories, and simple houses from the EBA (Di Nocera, 2010; Frangipane, 1997; Frangipane et al., 2001; Hauptmann et al., 2002b; Palmieri, 1981). Where the Taurus Mountains meet the north

Syrian steppe, Hacinebi has yielded copious evidence for late Chalcolithic copper smelting among an indigenous community that also hosted an enclave of settlers from southern Mesopotamia (Özbal et al., 1999). Finally, in the western sector of the Taurus, the 1980's and 90's saw a host of archaeometallurgical surveys that found numerous slag heaps and indications of ancient mining, among them the tin mining and smelting site of Göltepe-Kestel (Wagner et al., 1989; Yener and Özbal, 1987; Yener and Vandiver, 1993).

From Middle Bronze Age contexts there is a distinct paucity of archaeometallurgical evidence for mining and production activity, with most of our information deriving from the textual record of Kültepe, the ancient city of Kanesh. This archive, comprised of the personal and business correspondence of a class of Assyrian merchants, documents an extensive system of long-distance trade between Assur, located in modern northern Iraq, and a circuit of cities in central Anatolia (Dercksen, 1996; Larsen, 1976; Lehner, 2014; Maxwell-Hyslop, 1972; Veenhof and Eidem, 2008, pp. 45, 164–167). At the heart of this trade was the importation of tin and textiles from Assur in exchange for copper and silver. Though earlier interpretations tended to focus on the role of Assyrians as initiating and managing this trade (i.e. Özgüç, 2005, p. 29), a growing body of research has come to show that an inter-Anatolian network had been in operation since the EBA that the Assyrian merchants tapped into (Johnson et al., 2020; Massa and Palmisano, 2018; Şahoğlu, 2005). Initially, the presence of this earlier network was traced through a variety of distinct pottery forms (i.e. *depas* cups and Syrian bottles), many of which seem to represent skeuomorphs of metal vessels. With a close reading of the textual record in combination with new provenance studies, increasingly clear not only that substantial quantities of copper were being traded along this network from sources in the Black Sea region and the Taurus, but that they were being distributed across a large swath of the eastern Mediterranean

(Barjamovic, 2011, pp. 14, 262; Johnson et al., 2020; Sayre et al., 2001; Stos-Gale and Gale, 2010; Webb et al., 2006; Yener, 2015c). That shipments on the order of several tons at a time are attested in the texts for the MBA suggests that activities reached a scale of production rarely directly observed in the archaeological record of Anatolia (but see; Kaptan 1988, 226–27). In this case, it is problematic that many of the huge number of slag heaps surveyed by the Heidelberg team were of indeterminate age, but in all likelihood many of them conceal ancient material.

Within Kültepe itself the archaeological manifestation of this period has been detailed by Müller-Karpe (1994). Several workshops were excavated in the lower town, where the southern portion appears to have been occupied primarily by indigenous Anatolians, while the northern portion was occupied by a mixture of Anatolians and Assyrian merchants. It is from these latter contexts that the texts derived, as well as a variety of bellows, tuyères, molds, and pyrotechnical installations associated with metalworking (Müller-Karpe, 1994, pp. 49–65). This attests to an extensive secondary industry, which recent research has shown to be relatively consistent in the of copper, arsenical copper, tin bronze, and ternary alloys between the EBA and MBA (Lehner et al., 2015). Meanwhile, analyses[6] of Kültepe material originating from the lower town have revealed the presence of smelting slag, speiss, and large agglomerations of copper metal, tentatively suggesting the use of local copper-lead-zinc ores as well as a separate high-arsenic source. It is still too early to say whether the smelting slag represents on-site smelting or not, but copper deposits of the copper-lead-zinc variety are not uncommon in the region immediately northwest of the Taurus and Aladağlar (Pirajno et al., 2019, pp. 313, 512–513; Wagner et al.,

[6] Conducted by myself, to be published elsewhere.

2003, p. 483). This, in turn would suggest that in addition to procurement of metal via trade, there was also an ongoing local pattern of exploitation.

A small amount of evidence from the early 2nd millennium BC was also recovered from the site of Boğazköy (Hattuša), which later became the capital of the Hittite Empire. During this period it is known that the settlement was the host of another community of Assyrian merchants as part of the broader 2nd millennium trade network (Barjamovic, 2011, p. 292; Özgüç, 2005; Veenhof and Eidem, 2008, p. 41). It is in this context that early excavations at the site revealed a substantial structure containing a large hearth, a tuyère, and a variety of other finds including a complete deer antler. Although this space has been identified as a metal workshop (Müller-Karpe, 1994, pp. 68–69), the evidence is equivocal and renders this classification somewhat suspect. If this material may indeed be associated with a metal workshop, then the further observation that the remainder of the house was largely domestic in nature, but also contained a substantial number of seal impressions does lend some credence to the suggestion that the building itself may have been owned by someone other than the metalworker (Müller-Karpe, 1994, p. 70). In the early levels of the lower town, several buildings were excavated that yielded casting molds and crucibles alongside a variety of other tools related to craft production. This, in addition to tablet finds, has led to the identification of this area as the Karum (Assyrian neighborhood) of Hattuša (Müller-Karpe, 1994, p. 71), which allows for some parallelism in organization with Kültepe, although the level of preservation at Hattuša for these phases is poor enough that any such comparison is of limited validity.

Finally, for this timeframe the central Anatolian site of Kaman-Kalehöyük has proven to be another metallurgically active site. In addition to provenance data showing it to have been deeply involved in the inter-Anatolian copper trade (Sayre et al., 2001), the site has come to the fore with evidence for the precocious smelting and working of iron (Akanuma, 2008; Jambon, 2017). Although Early Bronze Age artifacts predating this material are known from sites such as Alaca Höyük, these examples are rare and their origin – that is, meteoric or smelted – is still contested (Yalçın, 2005, p. 494; Yalçın and Yalçın, 2018). The recent work at the site has shown, however, that not only was iron in somewhat regular use by the Middle Bronze Age, but its production may have begun during the Early Bronze Age (Akanuma, 2008; Jambon, 2017). At present, this is a still-developing field of research, and so the conclusions to be drawn are limited, but it does suggest that the eventual adoption of iron had relatively less to do with technological constrains and more to do with cultural concerns.

At the current state of research, probably the most thoroughly studied site of the Late Bronze Age is Boğazköy, where Lehner (2015) has undertaken an extensive evaluation of the EBA-IA assemblages using pXRF. This research has shown that for the Hittite milieu during the LBA, the metal industry was highly structured with a state operated mechanism for raw material acquisition and distribution and a clear division of labor. The primary focus in the city was on specialized secondary production activity with varying degrees of attached specialization evidenced by the variable location of metal workshops in both general urban as well as temple and palace contexts (Müller-Karpe, 1994, pp. 78–84). Metals, meanwhile, were extracted from outlying polities as part of an elaborate taxation scheme meant to concentrate wealth at the imperial core as part of a widespread wealth finance system (Lehner, 2015, pp. 178–192; Lehner and Schachner, 2017). Within this narrative a particular emphasis is placed on the continued expansion and elaboration of a two-tiered production model where primary and secondary working are geographically discrete, administratively controlled activities (Lehner, 2015, p. 179; Lehner and Schachner, 2017). However, as we will see later in this study, this model does not appear to have been uniformly applicable in the Late Bronze Age world and part of its efficacy may be related to the unique position of Hattuša as capitol of the Hittite Empire.

Outside Hattuša, a few sites have revealed interesting glimpses of change during this period, though the evidence tends to be less comprehensive. At Alaca Höyük, a smelting slag related to the processing of copper sulfide ores may indicate on-site smelting activity (Müller-Karpe, 1994, p. 87). Meanwhile, ores found in the Hittite occupation levels of Tepecik, in eastern Turkey, have a tin content approaching 0.5% (Esin, 1987, p. 71). Though this is too low for the manufacture of a natural bronze, it does suggest the presence of similar polymetallic ores that may have been more appropriate to the task. Meanwhile, material from LBI contexts at Kinet Höyük, on the opposite side of the Amanus Mountains from Tell Atchana, have yielded what may be indications of secondary processing of raw smelted material, however, more detail on this material will be necessary for any secure conclusion to be drawn (Yener and Dardeniz, 2017).

Up to this point, I have drawn the general contours of three academically defined metallurgical traditions in the eastern Mediterranean, stretching from the Late Chalcolithic to the Late Bronze Age. Among these, the Levantine and Cypriot industries are often held up as paradigmatic illustrations of how metallurgical industries were organized over the course of the Bronze Age. However, both examples lend themselves to clear delineation by virtue of their unique characteristics. That is, they are based on the exploitation of large, easily accessible deposits within geographically circumscribed areas. Particularly in the case of Cyprus, comparatively short transport distances and easy access to water represented an ideal confluence of factors making metal export a particularly profitable enterprise compared to land-locked systems. As a result, I would suggest that, far from being paradigmatic, these are exceptional examples that emphasize the distinct regionalism of metal production strategies elsewhere in the Near East, particularly in Anatolia. In circumstances where ore deposits are widespread and landscape conditions are ill suited to centralized administration, the development of metallurgical industries cannot be assumed to have been organized in a top-down fashion. Indeed, as discussed above, new considerations of the Levantine industry in the hostile desert environment of Timna are beginning to highlight this perspective.

The preceding discussion, however, is not comprehensive although it does represent the general picture for the eastern Mediterranean. Not included here is metal production further west in the Aegean and to the north in the Caucasus (Begemann et al., 2003; Catapotis and Bassiakos, 2007; Gale et al., 1985a; Georgakopoulou et al., 2011; Helwing, 2017; Wagner et al., 2011). The latter holds particular importance for iron and copper production (Erb-Satullo, 2019; Erb-Satullo et al., 2017, 2015, 2014), displaying extensive smelting of copper as well as production of copper and bronze objects, not to mention local traditions of working in precious metals (Gambašidze, 2001; Hauptmann and Klein, 2009; Stöllner et al., 2014). There are then the lowland metalworking traditions of Mesopotamia, largely ignored here, that are known to have been the crucible in which many complex techniques for secondary working were developed. The consideration of this secondary industry is the subject of several large studies, and is far too extensive to discuss here (Hauptmann et al., 2018; Moorey, 1994; Wilde, 2003). Finally, Iran is itself home to an extensive and diverse tradition of metalworking, which must be considered in communication with Anatolia, the Caucasus, and Central Asia. In short, what I have covered here is but a small part of the relevant material but must suffice for the current discussion.

## 5.2 Metals and Metalworkers in Texts

Because the textual record of the Near East developed from and focused largely on accounting of economic activity in relation to large institutions, a reasonable proportion of that data relates to the dispersal and use of metals for production, as well as its establishment as a standard of value. In this respect, these sources are invaluable because they provide us both with a glimpse of the massive quantities of metal in circulation, as well as the wide variety of objects produced. Indeed, they tend to highlight just how meagre the finds in the archaeological record truly are compared to what was manufactured. We also gain insight into how these institutions, primarily temples and palaces, organized their labor forces and, to a more limited extent, their material acquisition systems. We never hear directly from the craftspeople themselves, though we occasionally hear of them, and we never hear a word on the ultimate sources of the raw material. References to 'X-material of Y-land' seem most frequently to refer to the last place a material was shipped from. On occasion there is a toponym that identifies a mountain range with a certain resource such as "the silver mountain". Given powerful administrative oversight on other aspects of metals, this is a rather glaring omission.

In addition to economic texts, particularly from the Hittite state archives there are a range of esoteric ritual and narrative texts that frequently discuss metals in terms of metaphor. From these, it is possible to discern a few culturally specific understandings of metals. From the Mesopotamian realm, frequent mentions of the king as craftsman present us with an interesting, if not idealized account of the cultural perception of smiths. These bodies of material are relatively limited, however, leaving us with only a hint of how metals and metalworkers were perceived in different parts of the Near East. The texts from the Hittites, Ebla, and Ugarit are provide geographic and temporal context for the situation at Alalakh. As a contemporary territorial empire, the Hittites reflect decentralized modes of organization supplied by widely rooted tax-based procurement networks. Ebla and Ugarit, representing geographically proximal earlier and contemporary small states, are represented by trade-based procurement and stringent centralization of production. Alalakh falls into a similar class of state as the latter examples, though there is little indication of their level of state-controlled production.

Because Alalakh seems to fall somewhere between north Syrian modes of production and the more decentralized models seen in Anatolia, its archives provide an interesting case in the study of metals and metalworking. Though it is a palace archive and is therefore still primarily concerned with elite interests, Alalakh's subservient position in the competition of the Great Kings means that its overall focus is more locally grounded, focused on day-to-day administration. Because these archives date to periods preceding and contemporary to the assemblage discussed in this dissertation, they afford us a special opportunity to directly compare textual narratives with the residues of human action in the archaeological record.

### *5.2.1 Metals*

Most textual references to metals are relatively straightforward accounting records, focusing on quantities involved and the relative quality of material. They may be roughly divided into several types concerning initial accession into palace stores, disbursements for specific production projects, accounts of losses, and distribution of finished goods. Furthermore, there is a significant interest in recording grades of metals by quality and production technology when known, pertaining both to the production of tin-bronze as well as iron. Although we tend to suggest that ancient scribes were not especially interested in production technologies, this may be understood to suggest otherwise. Insofar as language is used to describe things that we encounter and work with daily, with those things that we are most concerned with receiving more specific terminology and elaboration, the vocabulary surrounding metals in texts is illustrative of the technical concerns of palace administrators.

Though not the earliest example of specific vocabulary for describing types of metals, the Ebla archives provide an excellent example of both material classification for raw and refined copper, as well as prescriptions for its use in the production of bronze. Waetzoldt (1981, pp. 364–366) initially associated refined copper with the term URUDU and raw copper with a-gar$_5$ and a-gar$_5$-gar$_5$, later reversing his decision in an article discussing the production of tin and arsenic bronzes (Waetzoldt and Bachmann, 1984, p. 8). The correctness of this reversal is suggested by the price differential between URUDU and a-gar$_5$-gar$_5$ of 1.6:2.05, indicating that the latter is at least a marginal value-added product. The fact that this was a distinction with meaning for the administration lies in the observation that, of 120 textual mentions, only refined copper (a-gar$_5$-gar$_5$) was meant to be used in the production of rings (probably ingots vis-à-vis Moorey (1994, p. 245)), while in another 100 instances it was used to produce tin-bronze. Neither raw copper nor bronze appear in either context (Waetzoldt and Bachmann, 1984, pp. 3–4). Regarding bronze, the specification of raw material to be used in its manufacture indicates a concern for standardized or reproducible material characteristics and an attempt to control them administratively. For tools, both raw copper (URUDU) and bronze (ZABAR) are used, but never refined copper (a-gar$_5$-gar$_5$).

Beyond specifying the materials to be used in the production of bronze, the Eblaite administration also dictated the composition of the bronzes produced.[7] The prescriptions often appear as: “One mina tin alloyed with seven minas of pure copper (12.5%), forged into objects

[7] Percent values given in parentheses refer to final composition of the bronze ordered.

for the carpenters” (TM.75.G.2428 rev. VII 47-52); “Nine minas (4.23 kg) of tin to be melted with 955 minas (444.85 kg) of copper (0.9%)” (TM.75.G.2622 rev. XXV 5-10); “Eleven minas (5.17 kg) of tin to be melted with 600 minas (282 kg) of copper (1.8%)” (TM.75.G.2502 obv. VIII 16-IX 6); “7 (shekels) of tin to be melted in <x-copper> (for) the visor of 1 helmet.” (TM.75.G.2359 obv. XI 10-14); “47 g of tin to be melted with 423 g of copper (10%): sheets (for decorating) one head of PN which (stays) on the gate of the king.” (TM.75.G.2429 obv. XXVIII 6-14) (cf. Archi, 2015). A similar situation is seen in a text from an unknown location, probably Iraq, that was mentioned by Waetzoldt and Bachmann (1984, p. 9): “1 mina (= 60 shekels) bronze, the related (production) losses: 4 shekels. The related tin: 8 shekels. The related copper: 5/6 minas 6 shekels (= 56 shekels) (12.5%). The related losses (during production) of purified copper: 7 1/3 shekel 24 gin. The related *sù-[gan]*: ½ shekel 6 gin.” Archi’s (1993a, pp. 618–619) listing of bronzes from production manifests rounds out the picture, citing 31 types of object, each of which has a specific associated tin content (0.8-21%) based on entries for 8,001 individual items.

Given this clear interest on the part of Eblaite administrators in the management and classification of metal resources and production there is an interesting omission from the documentation regarding arsenical copper. The discussion of potential sources or production sequences was the primary concern of the study by Waetzoldt and Bachmann (1984) cited above, for which they were unable to find a satisfactory identification. Since arsenical copper is well known to have been one of the primary alloys into the Late Bronze Age (or early Iron Age in Iran) (Eaton and McKerrell, 1976), appearing as a distinct class of material with compositions adjusted for use in tools, weapons, and ornamentation, this is a conspicuous oversight. One possibility is that URUDU could refer to either raw copper and/or arsenical copper. While possible at the level of coincidence, the specificity of use of the latter suggests that the difference was noted and understood, meaning that intentional grouping of the two under the same heading is unlikely. Another option is that whoever assessed alloy "recipes" and material characteristics (whether that is a smith-overseer or a scribe) worked in a somewhat arbitrary fashion, which might be suggested by the request for the production of an 0.8% Sn bronze (see above). What seems most likely, however, is that the administration was only documenting processes and materials over which they had direct control and that were valuable. This is why they mention tin shipped from Dilmun, but never the sources of their copper (Archi, 1993b, pp. 49–50). In this setting, arsenical copper could be said to constitute a vernacular alloy, a material that was relatively easily attainable and therefore was comparatively inexpensive and defied administrative control.

Hittite accounts often mention various grades of metal as well as different alloys. The Hittite sources use a terminology of normal and 'excellent' qualities of metals including gold (GUŠKIN vs. GUŠKIN $SIG_5$), silver ($KU_3$.BABBAR vs. $KU_3$.BABBAR $SIG_5$), and copper (URUDU vs. URUDU.$SIG_5$) (Siegelová and Tsumoto, 2011, p. 277), noting that ŠALMU is sometimes used in place of $SIG_5$. The Hittite terminology for iron is an exception, representing a more detailed categorization than is typically seen for metals in the Near East, with its broad reference to primary production method. Different words were used for the meteoric (AN.BAR $GE_6$), smelted (AN.BAR), and forged(?) (AN.BAR ša KI.NE) metal, in addition to good iron (AN.BAR $SIG_5$) and the more enigmatic white iron (AN.BAR BABBAR) (Košak, 1986; Siegelová and Tsumoto, 2011; Souckova-Siegelová, 2001). Though not especially informative to us, since we do not know the specific criteria for classification, these are still process-related technical terms. This expression of awareness regarding the circumstances of production, akin to the management of bronze manufacture at Ebla, suggests institutional involvement in its production. This is not a new idea, however, already being indicated by the oft-cited letter of Hattušili III to Adad-Nirari I, where the former is informed of iron production schedules in Kizzuwatna (Beckman, 1996, p. 140).

Despite Hittite terminology reflecting state involvement in the working of metals, our knowledge of alloying practice and material use from an administrative standpoint is relatively limited. Although Siegelová (1994, p. 121) has suggested tin-copper mixing ratios for bronzes based on KBo 18:164 and KUB 26:67, both of these are inventory texts documenting accession of metals into palace stores rather than disbursement. Not only are both texts rather incomplete, but only the former actually contains the word for tin (AN.NA) in a fragmentary state (cf. Košak, 1982, pp. 77–79 for transliterations), meaning that its overall presence is based on a (well) educated guess. Though the example of Uluburun is often presented to suggest that tin and copper were shipped together in proportions ready to produce "standard" 10% tin bronzes, there are only tenuous grounds for assuming that the quantities of metal shipped had any bearing on how they were ultimately mixed. Taking the Alalakh assemblage as an immediate example (see chapter 7), there is little reason to suggest that 10% represented a strong standard. This is supported by earlier material from Ebla and contemporary Boğazköy, with tin bronzes ranging between 0.8-21% in the texts of the former (Archi, 1993a, p. 619), and 1-20% in the analytical data of the latter (Lehner, 2015, p. 151).[8] What this means, simply, is that we have rather little trustworthy evidence for how the Hittite administration was controlling bronze production.

[8] In the case of the Boğazköy bronzes, the mean and median values are in fact around 10%. This obscures the fact, that there is a broad distribution of compositions on either side of this number (cf. Lehner, 2015, p. 147). It is suggested that samples between 1-5% Sn are recycled material. Though objects in this range are more likely to be recycled based on dilution of their original tin

Even if we are unsure of the specific details, we may reasonably assume that such a system was likely in place, given the evidence for disbursement of set amounts of metal for other projects. In KUB 26:66 (Košak, 1982, p. 68), the scribe notes: "5 minas of silver, 1 eagle-weight: (a) silver sun-disc they make. Thus Ehli-Kušuh: "Formerly (it was) with ᵐAN[]." 6 shekels of silver, 1 eagle-weight: the divinity of Arusna together with (its) pectoral they make. Thus Ehli-Kušuh: "Formerly (it was) with Kassu". 3 minas of silver, 1 eagle-weight: for two hauberks." In this context, Ehli-Kušuh the treasurer, is seen recording the distribution of silver for the production of cult objects. The phrase "formerly it was with X" may indicate that the individuals named were the smiths who produced the objects, the phraseology indicating that the material had changed hands could mean that the object had been completed and delivered to a temple, given that these are votive objects which frequently seem to have not made it back into palace stores (Siegelová and Tsumoto, 2011, p. 281).

This introduces an interesting set of Hittite ritual texts that frequently mention metal being used in a cultic setting. These reflect both potential symbolic and metaphorical understandings of metals as well as the creation of state assemblages produced in state workshops. This type of evidence is indicative of one role of the state in facilitating the creation of a technological style that likely stood apart from more vernacular traditions. The imbrication of metals in the language of cult, meanwhile, shows their deep entrainment in the cultural psyche of the Hittites.  The most noteworthy of these texts center around foundation rituals for temples and palaces (published in detail by Beckman (2010)). In one example:

> "When a new temple or a new structure is built in another location and when the foundations are laid, they place the following beneath the foundation

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content, as we have seen from the Ebla texts, this cannot be supported on compositional grounds alone.

> stones: one mina of… copper, four bronze pegs, and one small iron hammer. And inside, at the site for the column, (s)he digs up the earth and places the copper therein. Then (s)he nails it all around with the pegs, pounding (them in) with the iron hammer. And at the same time (s)he says as follows: "As this copper is protected and furthermore eternal, may this temple likewise be protected and may it be eternal up the Dark Earth!" (Beckman, 2010, p. 85)

> "(S)he places two foxes of copper in the main doorway. The weight is not at all important. ([S]he takes) sixteen apples, among which are four apples of gold, four apples of silver, four apples of iron, and four apples of bronze. The weight is not important." (Beckman, 2010, p. 87)

Here the symbolism of copper is rather directly stated in its association with permanence and durability. More importantly, this text illustrates how some of the votive objects, many of them miniatures, were used and deposited. While we know some are left in temples, others are deposited beneath buildings as part of elaborate cult proceedings. Though we typically do not find these archaeologically, such texts highlight the existence of an entire state assemblage reflecting a technological style geared toward the production of elaborate cultic goods, such as the well-known silver stag rhyton (van den Hout, 2018).

Going some way to illustrate the extent to which metals had made it into the Hittite metaphorical lexicon are two passages from KUB 29.1 concerning tin and iron:

> "Now you (the trees) come up from this land. The Storm-god has allotted you to the King. They shall place you in service… And they will speak many incantations up to you. Reveal that which is in your heart. If it is a crack (?), bring it out. If it is an evil…, reveal it. If it is a curse, reveal it. If sickness is in your heart of the illness of the Sun-goddess is in your heart, clean it out. The King, the Labarna, will come to you. [Let there be] tin and iron in your heart." (Beckman, 2010, p. 73)

> "They renew his (the king's) years. They renew (his) frightfulness. They constructed his body of tin. They made his head of iron. They made his eyes those of an eagle. They made his teeth those of a lion." (Beckman, 2010, p. 74)

In each of these, concerning the erection of a temple and the ascension of the king to the throne, both tin and iron appear as purifying, but primarily renewing and strengthening materials. For iron, the association appears relatively straightforward, being a particularly durable material. The possibilities for interpreting the mention of tin are more interesting. Here, an argument can be made that tin was conceived of as a material that, when added to the heart or core, removed weakness or impurity and was incorruptible. What this seems to discuss is a metaphorical alloying of the king. One wonders if such a line of thinking was responsible for the production of a 0.89% tin bronze at Ebla, the reasoning behind it being more rooted in symbolic rather than functional logic. If so, this would be an interesting example of a feedback loop characterizing the recursive relationship between technology and society, with a functional practice influencing ritual logic, which then results in materially non-functional practices.

In order to supply the Hittite metal economy, an extensive taxation and tribute system extracted copper, tin, silver, and gold from polities bound to the Hittite state as vassals. Within the textual record, locales such as Kizzuwatna (Cilicia), *Alašiya* (Cyprus(?)), and Ugarit are often listed as providing metals as tribute or gifts, while a larger number of place names are associated with the payment of taxes (Siegelová and Tsumoto, 2011, pp. 278–279). However, these locations do not necessarily correspond to the origin of the ores used to produce the metals. A straightforward example of this would be the mention of silver, gold, and copper from Ugarit in RS 17.221, which had no ore sources of its own. Based on Siegelová's (2011, p. 279) analysis, taxes were typically collected at royal storehouses in the form of finished goods.

> "1 copper pipe, the messenger (and) the chief of the body-guards[. 3 copper beakers: the people of Masa [brought them]. 2 copper sickles: the carpenters of Zi[planda brought them]. 8 copper spears, 9 copper cups, 3[ : the people of Zagapura (brought them): Wal[waziti checked it]." KUB 40:96 12-17 (Košak, 1982, p. 82)

After being noted in the storehouse registers, they were then melted down and cast into ingot forms before final shipment to Hattuša (Siegelová, 1994, p. 120; Souckova-Siegelová, 2001, p. 279). Müller-Karpe (1994, pp. 75–76) has provided a thorough analysis of the mentions of various metals in the inventory and tax documents, showing that a full quarter of Hittite tax income was in the form of raw metal, 60% of which was raw copper (13% silver and 8% tin), as opposed to 13% finished products. The discrepancy between Müller-Karpe and Siegelová's analyses regarding the nature of documented tax income may lie in the consolidation of finished objects into the form of ingots before shipment to Hattuša. In the storeroom inventories the situation is completely different, with 40% of goods being finished metal products, 60% of which were gold. What raw metal remained was almost exclusively silver. This suggests that copper was distributed for production at a very high rate, with finished goods then being further disbursed to as yet unknown persons (Müller-Karpe, 1994, pp. 77–78).

This situation stands in relatively stark contrast to the situation at Ebla and Ugarit where acquisition of metal at both sites seems to have been based on a system of what might loosely be termed 'elite merchants' that constituted part of the palace administration. Once acceded into palace stores, distribution of raw material as well as finished metal products was strictly accounted for. At Ebla, metals were provided to palace stores through the activities of the "vizier", one example being an individual named *Ibbi-zikir*, who contributed some 5,127kg of silver, 139kg of gold, 4,929kg of copper, and 48,779 pieces of clothing to palace stores (Archi, 1993b, pp. 47–50). While it is unlikely that he was personally responsible for delivering this material, it does appear that he at least organized its acquisition. In similar fashion, an individual from Ugarit by the name of *Yabninu*, whose house contained a large number of documents concerning international diplomacy and also held military rank, is listed as providing goods such as tin and iron to the palace (Bell, 2012, p. 183; McGeough, 2007, p. 183). Other individuals from Ugarit such as *Rapanu* and *Rašap-abu* appear to have served a similar purpose with equally strong ties to the palace administration (Bell, 2012). A significant difference between these two cases, however, lies in amounts of metal received through tribute. Compared to the income provided by *Ibbi-zikir* listed above, outlying settlements provided only 162kg of silver and 40kg of gold to Ebla. Meanwhile, KTU 4.43 lists 1,108 talents (31,245kg) of copper provided as tribute to Ugarit that was then delivered to state-sponsored smiths (McGeough, 2007, p. 194). In both Ebla and Ugarit, once smiths had received raw materials and completed a production order the finished goods were returned to the palace an accounted for, as shown in various lists of tools which document quantities and compositions (Archi, 1995). In the same documents, there are also records of tools issued to individuals with specific professions such as carpenters. Similarly, at Ugarit, farms were provided equipment by the state, among which were a complement of tools. In issuing these materials, the administration documented the "price" of these objects in copper, which happened to also be their weight (Liverani, 1989).

Based on this discussion, several points come to the fore regarding the interest of ancient scribes in metals. The first is that there does appear to have been an interest in technical aspects of metal production, but only in those practices the state could control and had a stake in. This is seen in the Eblaite strictures on the production of tin bronze juxtaposed with the omission of arsenical copper, as well as in the Hittite terminological documentation of iron. In the first instance, control of bulk tin resources acquired through trade allowed the state an essential monopoly on the production of tin bronze, while a desire to maximize productive efficiency and manage valuable resources resulted in a routinization and standardization of production. For iron, though unpredictability in the production process at this time probably made it unattractive from an accounting and mass-production perspective compared to copper, its importance in cult and ritual meant that there was still state interest in its production. Since iron ores are readily available in many geological settings, the topographic and cultural issues presented in chapter 4 were unlikely to pose a significant problem. Looking at material acquisition patterns, the Hittite state seems to have functioned as a typical extractive empire, attempting to concentrate resources at its core through taxation with relatively little indication of trade and a seemingly lax[9] control of metal resources (except gold and silver) on they were in the core (Hoffner, 2002a). By contrast, the examples of Ugarit and Ebla appear primarily to be driven through a form of mercantilism or palace-centered trade. Once metals had entered these systems, the level of control and monitoring of their movement was significant.

### *5.2.2 Labor Organization*

Determination of labor organization from ancient texts often relies of isolated statements or inferences drawn from ancient terminology. In a few rare cases the sources are more explicit in discussing the management of labor, but these are associated with more stringently organized production systems (Ebla and Ugarit) that are not necessarily representative of the mechanisms in place in other Near Eastern societies. Though both the Eblaite and Hittite records reflect top-down organization of production, the Hittite system does not appear to have integrated all smiths as palace dependents, as opposed to the Eblaite administration which seems to have encompassed all smiths and maintained them through a massive staple finance system. In both cases there is a significant emphasis on standardization and routinization of production, which is interpreted as a hallmark of cost-conscious systems of specialization, frequently (but not always)

[9] There is an issue here in that there was a body of Hittite texts written on wood that we do not have access to. Short-term archives such as metal disbursement may have been written on these, leaving us no record of this level of control (Waal, 2011).

associated with state infrastructures (Costin, 1991, pp. 33–34). The Hittite evidence points toward the development of a segmented specialization structure with different classifications for individuals working in different metals, in addition to the generalized "smiths". In the Eblaite and Ugaritic evidence there is an indication that bureaucratic measures to simplify smithing procedures was meant to manage costs and lower the knowledge threshold for working as a smith.

The Hittite inventory lists are reasonably informative in their accounts of materials entering and leaving the royal treasuries. In the case of gold, we have textual records of material being disbursed for refining, often with the same names being mentioned multiple times (Košak, 1982, p. 73).

> "[x minas] of gold: receipt from the chest is miss[ing]. [P]alla and Zuzuli will refi[ne it]." KBo 18:153 4-5 (Košak, 1982, p. 73)
>
> "1 mina 10 shekels of good gold with copper, (in) stone-weight, thereof 1 stone (of) 1 mina, 2 ditto (i.e. stones) of 10 shekels; a large mountain is made. The hand of Zuzuli. 1 mina 10 shekels of good gold with copper, (in) stone-weight, thereof 1 stone of 1 mina, 2 ditto of 10 shekels; a large crocus is made. The hand of Zuzuli. 1 mina of good gold with copper, (in) 1 […]-weight; a large finger is made. The hand of Zuzuli. [x+]20 shekels of good gold, (in) 1 eagle-weight; they make (an implement for) tying up. [The hand of] Alamuwa."

Both Palla and Zuzuli are figures known from other texts, and their cylinder seals were excavated in the same room at Boğazköy. "The hand of X" is a phrase indicating that the material has been turned over to the named individual for the purpose listed (Košak, 1982, p. 93). As can be seen here, these activities included both the processing of new material, as well as the production of cultic objects. Meanwhile, the limited recurrence of names may suggest that the number of goldsmiths in the service of the palace was fairly limited at any one time.

KUB29.4, a ritual text for building a new temple to the Night Goddess, gives us slightly more context in this process.

> "One sun disk of gold of one shekel (weight), its name is Pirinkir. One gold navel. One pair of gold *purka*. – they are set with Babylon stone. The priest assigns these to the smiths as their task." CTH 481 (Collins, 2003, para. 3)

While the inventory lists record the simple distribution of material for the production of an object, this text shows the circumstances under which the disbursement would be made. In this case, a priest has ordered the smiths to produce cult objects for the establishment of a new temple.

While the documentation surrounding gold is relatively detailed, for copper we are somewhat less fortunate. While the lists tell what is to be produced, we do not generally know who made the request, nor who is fulfilling the order. One exception is the fragmentary account of KBo 18:161 rev. 5-10.

> "A total of 153 minas of copper from Anku[wa]. Zikkuwa (is) their supervisor… 21 minas of copper: for 3 bath-tubs and 3 clepsydras: Hila-KAL of Anzilatassi… x minas of copper for 3 chariots, thereof 1 orange-yellow: Alihesni and Santa." (Košak, 1982, p. 105)

Unfortunately, it is not immediately clear from the context what the individuals mentioned are actually doing. In the case of Zikkuwa, it would appear that this individual was merely escorting this large quantity of metal to ensure its safe delivery (cf. Hoffner, 2002a). For Hila-KAL it is unclear whether they are distributing the copper or receiving it for production, while Alihesni and Santa would seem to be receiving the material for production.

Further evidence on segmented specialized labor can be found in the terminology surrounding metalworkers. In particular, by about the 15th century BC, Hittite records begin noting coppersmiths (LÚ URUDU.DÍM.DÍM), iron-workers (LÚ.MEŠ AN.BAR), silversmiths (LÚ.MEŠ KÙ.BABBAR), and general workers in precious metals ($^{\text{LÚ.MEŠ}}$KÙ.DÍM) suggesting a high degree of specialization between smiths as well as the creation of occupational corporate groups (Siegelová, 1994, p. 120; Siegelová and Tsumoto, 2011, p. 281). The ceremonial nature of the texts that mention these groups makes it difficult to establish the extent to which these classifications impacted organizational structures in daily life, however. In this respect, the mention of an overseer of smiths (using still another word for smith – E.DÉ.A) in KBo 10.23 I 22-28 is intriguing: "The overseer of the smiths holds a ceremonial iron spear. The chief of the palace servants takes the chief of the smiths (by his) cloak and leads him in (to the presence of the king."

If such a figure existed within the actual organizational structure of the production system, this would seem to indicate a multi-tier hierarchy. If nothing else, the breadth of terminology for smiths – also including $^{\text{LÚ}}$SIMUG and $^{\text{LÚ}}$TIBIRA – would seem to imply a more complex classification structure than we are able to comprehend based on the available data. A Hittite law (KBo 22.62 III 24.f +KBo 6.2 III 21f. Law§56) does seem to support the notion that at least smiths working in different materials had variable responsibilities, specifying that "No copper-worker ($^{\text{LÚ}}$URUDU.⸢NAGAR⸣) shall be exempted from being assigned to a royal expedition for (work) on ice(-cutting) or on fortification work, (or) from harvesting of vineyard(s). The gardeners too shall perform corveé in all the same (duties)."

The Ebla present relatively more detailed information on the organization of labor surrounding metalworkers and their role as palace dependents. The entire working population of the city appears to have been organized into work groups referred to as é-duru$_5^{\text{ki}}$ that consisted of approximately 20 persons. These were then organized into larger mobile work groups called *ìr-a-*

*num* that were placed under the control of a palace functionary. Within the documents recording these units, Archi (1988b, p. 28) has determined that the palace employed around 500 smiths at one time in association with the *ìr-a-num*, all members of which were provided with both food and clothing. In addition to these seemingly mobile labor units, a further organizational structure existed referred to by the term é (house), 4,580 of which are listed in TM.75.G.10250 (Archi, 1988b, p. 28).

It is not clear from the texts mentioning é-simug (House of the Smiths) precise how many individuals would have been employed in these productive units at any one time, since it appears that the palace simply made bulk deliveries of foodstuffs to the suburbs housing these units, with the smith overseer (ugula simug) being responsible for distribution (Archi, 1988b, p. 28). Of six apparent mentions of é-simug in the Ebla texts, one of them (TM.75.G.00535) contains two mentions that reference 200 loaves of ninda-sikil, which would literally translate to pure/divine bread. As such, the exact meaning is not immediately clear to me. Nevertheless, the regulation of their activity was substantial – as seen in TM.75.G.2428 rev. VIII 1-15, where new tools for carpenters are being ordered:

> "The House of the Smiths; 1 mina 2.5 shekels tin alloyed with 7 minas 17.5 shekels pure copper for the production of 4 small axes of 30 (shekels), 4…chisels of 20 (shekels), 4 narrow chisels of 20 (shekels), 4 narrow chisels of 15 (shekels), 4 narrow chisels of 10 (shekels), 4 'teeth' of 10 (shekels), 4 ḫa-ra-an tools of 7 (shekels), 4 ma-za-ḫa-lum tools of 10 (shekels) … that will be newly manufactured for the carpenters"

For the most part, it seems that individual smiths are mentioned only infrequently, suggesting that most of their activity was as part of these types of corporate entity. The few mentions seem typically to remark on the distribution of clothing to them. One exception would be the case of Puzurra-UTU, a smith from Mari, who received 2 minas of silver to cover his travel costs. As will be seen below, this likely meant that he was a particularly talented individual that afforded him the ability to travel on official work.

In the Hittite, Eblaite, and Ugaritic cases the tendency toward standardization in terms of weight and composition is striking. This would have facilitated two goals: the simplification of resource management and exchange, as well as the routinization of production. In all three instances, weights of objects such as axes, spears, knives, and sickles were determined by the administration, as demonstrated above with evidence from Ebla (Archi, 1995; Liverani, 1989, pp. 136–138; Siegelová, 1994, p. 120). This type of regulation may have even resulted in the creation of a relatively standardized set of forms for these objects, as suggested by the specific chisel terminology listed above. By controlling the quantities of metal used in the production of given types of object, administrators could more effectively account for precious resources with the side effect that this directly linked such objects into established systems of value such as those specified in the Hittite laws. In KBo 6.26 II 32-33 Law § 178 "the price of a plow ox is twelve shekels of silver, the price of a bull is ten shekels of silver; the price of a yearling plow ox or cow is five shekels of silver." In Ebla the primary motive of these measures was likely accounting and routinization since the entire city was dependent on the palace to one degree or another and it is not clear to what extent private trade existed within the city (Archi, 1993b, p. 49). Considering the huge number of smiths employed by the palace, this was probably facilitated by routinization of production intended to minimize the degree of personal expertise necessary. In a command economy of this scale, where the range of goods to be produced on a regular basis was not especially great, it made more sense to have "recipes" that could be followed by many workers operating with minimal autonomy. If we assume that administrative similarity between Ugarit and Ebla extended to this level of management, the practice of imposing new professions on individuals in the former (van Soldt, 2015, p. 572) would make such simplifying measures necessary.

### *5.2.3 Sources of Labor*

Having gone through the rough outlines of institutional metallurgy in the 3rd and 2nd millennia BC, there remains the question of where the labor involved in these organizational schemes originated. The data on this topic are exceptionally scarce, though a few examples can be noted. The two primary methods of labor acquisition are through forcible recruitment and apprenticeship. It is difficult to establish which of these was more common based on the scarcity and ambiguity of information. Once individuals were working in the service of states, however, it appears that the authorities went to significant efforts to retain labor. This would tend to reinforce the image presented so far of regulated production systems.

In Hittite law §200B evidence for the explicit training of craft specialists is presented in a context that also hints at the existence of specialized labor outside of the state sector:

> "If anyone gives his son for training either as a carpenter or a smith ($^{\text{LÚ}}$SIMUG), a weaver or a leatherworker or a fuller, he shall pay 6 shekels of silver as the fee for training. If the teacher makers him an expert, the student shall give to his teacher one person" (Hoffner, 1995, p. 237).

This law indicates that there was a certain degree of social fluidity that allowed for changes in occupation through the acquisition of education. Furthermore, that this seems to represent situations obtaining between private individuals, it would seem to imply that at least some smiths existed as private practitioners. Considering the commentary above on the subjection of copper smiths to corveé requirements like any other common citizen, this would seem to be supported. In a similar vein, a text from Nuzi states: "the students PN and $PN_2$ are given to $PN_3$ for training in smithing. When the master teaches them, the lord (owner?) of the students gives 30 shekels of silver to $PN_4$" (Salonen, 1970, p. 131). The fragmentary nature of the text renders interpretation difficult, however, it does appear to suggest that (a) the education of smiths in northern Mesopotamia was more expansive than in Ḫatti and (b) at least the students in this case may have been slaves. Salonen suggests that $PN_4$ was a colleague of $PN_3$, but it is equally likely from this context that the latter was the slave of the former. Finally, in Ugarit there seems to be an implied system of apprenticeship or education based on the royally mandated transfer of occupational duties with the transfer of land ownership (McGeough, 2007, p. 188; van Soldt, 2015).

From Mesopotamian and Hittite records, we find fleeting episodes lending support to an origin of at least some craftspeople as prisoners taken on military campaigns. In the epic of Lugalbanda, after the protagonist receives instructions from the goddess Inanna on how to break the defense of the city of Aratta, he is told: "If he carries off from the city its worked metal and smiths, if he carries off its worked stones and stonemasons, if he renews the city and settles it, all the molds of Aratta will be his" (Black et al., 1998, ll. 409–412). While hypothetical in tone, this excerpt does establish metalworkers and their equipment as an important class of war booty. More concretely, however, is the 1st millennium BC Neo-Assyrian deportation of all the goldsmiths in Judah in similar fashion (Moorey, 1994, p. 223). Finally, Košak (1982) makes a secondary citation linking the goldsmith Zuzuli, mentioned above in the Hittite inventory lists, to NAM.RA people, or civilian war captives. If this identification is reliable, it would place a high-ranking metalsmith within this class of individuals.

Although Zaccagnini (1983, p. 245) claims that the use of slaves for specialized labor was rare in the Near East, texts from Mari suggest that even if specialists were not slaves, they also were not free. In ARM 1 14: 5-15, a letter between king Šamši-Addu and his son, Iasmaḫ-

Addu, the former states: “I have inspected the cooks, and there are far too many in the service (of) *wedu*. Now, Abdu-Naw[ir(?)] and (?) Ṣillima-II who….. are at your home. At the reading of my tablet, reinforce their guards and send (them) to me with a trusted man and the bearer of this tablet”. As seen in a text from Ebla, however, some smiths could achieve high status that allowed them to travel or be sent abroad. According to Waetzoldt (2001, p. 189), his Text 25 is one of a series of texts documenting royal expenditures to fund the travel of palace dependents. Though brief, simply stating “2 minas of silver for Puzurra-UTU, the metalworker from Mari”, this text documents a significant outlay of silver to a single individual, the lack of a work order suggesting that it was intended for his own use. This jibes well with other sources that document the short and long-term exchange of particularly talented smiths between the royalty of Mesopotamia and north Syria (Sasson, 1968; Zaccagnini, 1983, p. 248).

Based on this limited evidence, it appears that modes of labor acquisition were relatively diverse. Teaching or apprenticeship appears to have been a significant method, with it being a frequent enough occurrence for the Hittite state to have established tuition rates. As we have seen from Nuzi, this does not necessarily mean that the persons involved were free, and there is an implication that a master could send his slaves to be educated. In addition, captives taken in war were another likely source of specialist labor. Though examples specifically related to metal workers are scarce, Hoffner’s (2002b) study of the treatment of Hittite battle captives shows the extent to which the Hittites incorporated them into their own society and Košak (1982, p. 73) has suggested that the Hittite goldsmith Zuzuli was originally one such captive. Finally, though not discussing how the workers were acquired initially, the texts from Ebla and Mari provide examples of how semi-free or slave labor could be moved within and between kingdoms to provide labor where necessary.

### *5.2.4 The Alalakh Texts*

Having undertaken a partial overview of metals and metalworkers in the Near East, this brings me to the textual corpus of Tell Atchana itself. These texts originated from archives in both palace and temple contexts covering limited periods in the 17th and 15th centuries BC. The material from Tell Atchana gives us a substantial quantity of detailed demographic data about Mukiš, the small kingdom of which Alalakh was the capitol, including class membership and occupation. I will limit myself largely to the LBA material, though some reference will be made to MBA texts where relevant. This body of material allows us to focus on several areas relevant to the above discussion – first, the social status of metalworkers; second, the organization of production; and third, issues around the procurement of metals. When compared to the above examples, the administration of Alalakh displays a similar penchant for classifying its population while also appearing less heavily centralized. There are no ration lists to speak of for metalworkers and accounts of metal disbursements from the palace are limited. Further, standardization of production is less pronounced, while there is some implication that smiths working for the palace in some contexts may have been paid for their labor. Though these similar features stem from a common political milieu of the Bronze Age eastern Mediterranean, I believe the significant differences stem from Alalakh's proximity to the highland-lowland interface and the affordances, limitations, and social interactions that it provides.

Von Dassow (2008, p. 252) has undertaken an exceptionally thorough study of the 15th century corpus of Alalakh, finding that the society was split into a quadripartite division of *maryanni*, *eḫelle*, *ḫaniaḫḫe*, and *ḫupše*. Within this class schema, the *maryanni* were the chariot warrior nobility of Alalakh, the *eḫelle* constituted a class of specialized craftspeople, while the *ḫaniaḫḫe*, and *ḫupše* are broadly construed as the peasantry. Among these groups the *eḫelle* are often listed as having a specific occupation (i.e. smith, carpenter, leatherworker), which they carried out either independently or in the employ of someone of higher rank (von Dassow, 2008, p. 264). In addition to the *eḫelle*, we also have attestations for specialists, including smiths, of the *ḫaniaḫḫe* and *ḫupše* classes, meaning that having a trade did not equate with a rise in social status. The difficulty of determining the relative social capitol of these groups is further compounded by the fact that the *eḫelle* are never recorded as owning property aside from land complicates differentiating them from the *ḫupše*, and it is entirely possible that there was no substantial difference (von Dassow, 2008, pp. 332–334). Indeed, the primary point of distinction is that only the *eḫelle* are regularly listed as having employers. This may mean that this social label amounts to a statement that this person is known to the administration as a reliable and trustworthy craftsperson, making them eligible to substitute their specialist labor for their otherwise mandated corveé duties (von Dassow, 2008, p. 330).

Being an *eḫellena* did not automatically mean working in the employ of the elite, it merely meant that it was more of a possibility. As von Dassow (2008, p. 264) notes, some 60% of *eḫelle* had a specified occupation, as opposed to only 49% having an employer. This already suggests that a significant portion of the specialist population spent their time working independently, periodically being hired for a specific job or being required to perform a service duty. Though we do not know the class of the smiths involved, the latter is likely attested in AlT 401, documenting a disbursement of 4 talents and 1000 shekels of pure copper (URUDU.SIG$_5$) to smiths in *Benta-mušuni*, only 400 shekels of which was specified for arrowheads. A similar situation prevails in AlT 402, where 4 talents of copper were disbursed, 4000 shekels of which were designated for arrowheads and 600 for doors. If we follow the Ugaritic weight system with a 9.4g shekel and a 28.2kg talent (Stieglitz, 1979), then this leaves 69.5kg of copper unaccounted for on an undamaged tablet. Given the specification that a certain quantity of metal was understood for a specific task, this may suggest that the remainder was intended as payment. By contrast, another set of disbursements exists that simply documents a quantity of metal given for a particular task, such as 7 talents of copper for the production of 2000 "baskets" (AlT 397). While we might understand that all 7 talents were meant to be used for this purpose, it is also possible that any leftover material was considered profit for the smiths. More concretely, AlT 227 specifically documents the presence of 16 smith households that were required to produce vessels and weapons as part of their explicitly stated work obligation (von Dassow, 2008, pp. 320–321), implying that they were left to their own devices otherwise.

In Costin's (1991, p. 8) terminology, the situations outlined above would appear to fall somewhere close to the category of nucleated workshops, referring to "larger workshops aggregated within a single community, producing for unrestricted regional consumption", albeit with elements of dispersed corveé. As opposed to craftspeople working at Ebla and Mari in the 3rd and early 2nd millennia, illustrating instances of fully attached specialization, with institutions providing work materials, clothing, and sustenance, there is no indication for this type of relationship in the Alalakh corpus (von Dassow, 2008, pp. 330–331). In fact, aside from the suggestion above that quantities of material in excess of that needed for a production order may have been payment for services rendered, there is no direct indication of how the palace or elites may have compensated specialists either in materials or in rations. Unfortunately, the fragmentary nature of the texts (only 4 smiths in the census vs. 16 in AlT 227!) means that the accounts given in the extant documents are incomplete, leaving us with only a partial picture. This point is further reinforced when we turn to other documentary evidence for substantial populations living outside state control such as the *ḫabirū* (von Dassow, 2008, pp. 344–348) and

SUTI-men (AlT 228)(Wiseman, 1953, p. 80) and the fact that some of them are known to be smiths as well. This on its own points to a population of specialists in the area of Mukiš who were not even bound to the known settlement apparatus, much less that of the state.

For all the discussion of copper, silver, and gold in the Alalakh texts (tin is mentioned once), the terminology is rather poor compared to previous examples and there is almost no mention of where this metal originated. In terms of terminology, of ten texts (AlT 2, 17, 46, 56, 327, 396, 401, 430, 431, 434) mentioning copper, only one mentions URUDU.SIG$_5$, while all others simply mention copper: *erû*/URUDU. As elsewhere, bronze is ZABAR, but there is no discussion of how it is to be alloyed. In terms of acquisition, the evidence is equivocal. AlT 431 was understood by Wiseman (1953, p. 14) to indicate that copper was delivered to the palace as bars and from there distributed to smiths, however, his translation of the text as saying "copper made into bars" could imply both a distinction in how copper was delivered, as well as a processing step undertaken at the palace. The one instance in which the origin for metal is given is in AlT 385, which lists 15 shekels (141g) of silver of *Alašiya* (Cyprus). Given that Cyprus is not generally known to have silver deposits, this would have simply been shipped from *Alašiya* and not produced there.

## 5.3 Conclusion

Starting from a discussion of wealth and staple finance systems, I have attempted to illustrate at least part of the reason why craft specialization and metals are an important component in, and noteworthy expression of, complex social organization. This perception has led to the establishment of a causal link between urbanization and social hierarchy on the one hand, and metal producing industries and long-distance trade on the other. This is most frequently supported with reference to the unique metallurgical industries of the Levant and

Cyprus under guise of the suggestion that only hierarchical organization structures could facilitate developed mining and smelting operations. The Anatolian evidence, and re-evaluation of some Levantine evidence, suggests a wider range of possibilities. Contrary to the current paradigmatic status of Cyprus and the Levant, a comparison of these cases illustrates the extent to which topography and social proximity play deciding roles in how the technology-society relationship is structured, as discussed in chapter 4. In this respect, the configuration of society across the landscape is a potentially stronger determining factor in the development of technology than simple social complexity.

When viewed from a textual perspective, there are significant elements of commonality and divergence between Alalakh, the Hittites, Ebla, and Ugarit that go some way to support this perspective. Despite being in the same geographic region as Alalakh, Ebla and Ugarit exhibit strongly centralized production systems with distinct elements of state-supported and moderated trade. To use an anachronistic term, the evidence suggests that both are distinct command economies, at least where metals are concerned. What distinguishes these locales from Alalakh is that their relative distance from ore sources means that their acquisition of metal is more heavily dependent on long-distance trade. This distance presents another factor which is that both cities are less likely to have access to what we might call indigenous metallurgists, instead being reliant on individuals trained simply as smiths. The distinction here is that an indigenous metallurgist would be someone who knows of ore sources and is proficient in primary and secondary metallurgy, while the smith is proficient almost exclusively in secondary work. The result is that administrations such as the Eblaite and Ugaritic are concerned with cost and resource management, as well as finding ways to efficiently expand their specialist labor pool. Alalakh, lying near metalliferous highlands, is more likely to have had significant highland-lowland population flux, some of which would have involved such indigenous metallurgists. Without an effective means of limiting access to resources, the type of institutional control at Ebla and Ugarit was neither practical nor feasible.

In relation to the Hittite example, Alalakh shows greater commonality in its decentralized distribution of labor. I suggest that this similarity is an artifact of scale, that these similar patterns developed for different reasons. In the case of Alalakh, a decentralized pattern formed in an environment where landscape and social factors made strict institutional control more difficult. For the Hittites, their large imperial footprint provided them access to a wide variety of resources, as well as to a large pool of potential labor – both due to areal extent of the empire, as well as captives from military campaigns. In such a setting, it was potentially neither necessary nor desirable to establish the type of centrally administered workshops seen in Ebla and Ugarit. Instead, individual workshops could operate privately, producing for the state on-demand but otherwise operating within the local economy. There were centralized workshops, to be sure, but these seem to have been primarily concerned with the working of precious metals. Thus, we find ourselves with a loosely regulated lowland metallurgical industry characterized by its proximity to ore resources and highlands on the one hand, and a semi-highland empire with a decentralized but more structured metallurgical industry on the other.

As will be shown in the following chapters, the operative distinction here appears to be that while the industry at Tell Atchana had a component characterized by the presence of indigenous metallurgists and primary metallurgy, the Hittite industry has been historically characterized as a secondary endeavor. It seems to me that such highly structured industries are likely to be a result of situations where the state controls all or most of the raw material supply. This would mean that until the state was able to project substantial power into highland resource zones, such control would largely be limited to secondary industries, except in unique situations such as Cyprus or (parts of) the Levant. If specialists were in control of all aspects of their production, the state was forced into a position of offering greater autonomy and incentives to maintain a local industry.

# 6 Optical and Scanning Microscopy

The use of both optical (OM) and scanning electron microscopic (SEM) techniques is a critical element to any assessment of metallurgical assemblages. While optical techniques are frequently underestimated, their low cost, combined with the variety of data that can be obtained makes them an ideal first step in analysis, although the time investment to achieve competency is significant. Nevertheless, the availability and minimal maintenance requirements of most OM equipment means that the user can conduct analysis with minimal time constraints and service interruptions. When considering SEM techniques, the interpretation of images is often a more direct exercise, but the loss of certain textures and colors in grayscale secondary and backscattered electron images means that a significant amount of the information gained from optical microscopy is lost. The true strength of SEM analysis for archaeometallurgy lies in its combination with energy dispersive spectroscopy equipment (EDS), allowing the user to obtain reasonably accurate measurements of elemental composition for both bulk and phase analyses, the latter of which is particularly complimentary to OM results. While the interpretation of this data requires at least a working knowledge of chemistry in general and metallurgical chemistry in particular, such information is most certainly more readily accessible, well-documented, and codified than the skills used in OM. The primary downside for SEM-EDS analysis is the issue of costs and maintenance, where the user can often end up paying hefty hourly fees for instrument time and is faced with the prospect of periodic service outages due to machine failure or maintenance visits. With these characteristics under consideration, these two techniques are highly complementary and most effective when used in tandem.

At present, there is no commonly accepted handbook for the analysis of archaeometallurgical materials by OM and SEM-EDS, meaning that the methods and standards of evaluation given in the literature are a morass reflecting the diversity of approaches and educational backgrounds seen in archaeometallurgy. The closest approximation to a methodological canon comes in the form of three books: Bachmann's (1982a) *The Identification of Slags from Archaeological Sites*, Scott's (1991) *Metallography and Microstructure of Ancient and Historic Metals* and *Ancient Metals: Microstructure and Metallurgy* (2010), and Rostoker and Dvorak's (1990) *Interpretation of Metallographic Structures*. To these texts, we may add the more recent volume by Roberts and Thornton (2014) – *Archaeometallurgy in Global Perspective: Methods and Syntheses* as well as the general set of ASM publications on metallography (ASM International, 2004; Vander Voort, 1999). Because of the significant variation in ancient metallurgical technologies and the questions asked of their analysis, these texts cannot possibly hope to prepare the student for every possible scenario they may encounter, leaving them as a rough starting point. While I have attempted to be as thorough as possible in this work, I chose my methods with specific questions and methodologies in mind. As such, there is still significant room for further research on this assemblage beyond what is presented here.

In the present project, OM served as the first analytical step followed by SEM-EDS. The primary goal of OM was to generate broad classifications of material based on outstanding features to aid in organizing data, while also noting and contextualizing the unique features of each sample. I then used this information to prioritize features for analysis via SEM-EDS, during which I made phase and bulk compositional determinations to help confirm or revise my OM observations. Overall, the classifications developed during the OM phase of analysis proved robust, yielding the following categories with minor modifications based on compositional data:

High Tin Bronze, Raw Copper, Refined Copper, Low Tin Bronze[1], Heterogeneous Smelting Product (HSP), Speiss, Cupronickel, Cu-Ag-Ni, Gold, Crucible Slag, Smelting Slag, Workshop Floor. The summary of metallographic observations can be found in appendix 1.

In the following pages, I will present the sample preparation and analytical methodology used for OM and SEM-EDS analyses. This will be followed by a discussion of the criteria used to define each category of material and detailed presentation of OM and phase specific SEM-EDS analyses where pertinent. In cases where there are relevant comparanda from the archaeological literature, those will be given as well. Finally, I will close with a general summary of the technological footprint and activities suggested by these analyses. Due to the categorical nature of the data in this chapter, I have largely chosen to ignore the chronological limitations of the assemblage in favor of presenting a more coherent picture. For the chronological and spatial associations of the material discussed here and in the next chapter, see chapter 9.

Within the broader scope of this project, microscopic evaluation of the assemblage serves as an initial basis for defining the technological style of the industry at Alalakh. This includes establishing what types of material are commonly worked with in the workshops, and if these are used for clearly defined purposes such as tool or weapon manufacture, or decoration. Additionally, this data is crucial in identifying less commonly encountered practices such as surface treatments, which constitute often missed but important parts of technical practice. For the Alalakhian industry, I have been able to identify weak patterning that suggests different uses

[1] The categorization of Low vs. High tin bronze used here is based on bulk compositional trends seen in the assemblage, but also reflects a convention seen in some modern industry (Nadolski, 2017). However, Scott (1991, p. 25) also outlines a classification criteria based on solubility of tin in copper with high-Sn bronzes being 17% Sn and above and low-Sn being below 17%. Because this scheme is not reflected in our data, the transition point of 6% Sn is retained in this work.

and working regimes for low and high tin bronze, as well as refined and raw copper. Beyond this, there is evidence for the use of at least two varieties of surface treatment, and an example of composition segregation of questionable intentionality. Finally, examination of the slag assemblage and samples of workshop floor suggest that the Area 4 workshop hosted a self-contained metallurgical productive system. Overall, though there is a clear difference in the absolute range of processes being conducted in Area 1 and 4, from a general perspective the range of techniques and use of material exhibited in terms of secondary metallurgy suggests a reasonably cohesive tradition of metalworking within the sampled assemblage.

## 6.1 Methods

The methodology employed here follows well-established procedures for analysis of metallurgical and mineral samples. Candidate objects were chosen based on the relative proportions of artifact types present in secure contexts. I tried to keep ratios of slag to finished objects to waste metal representative of the excavated assemblage, though this was often not practical due to preservation issues. Small fragments were cut from approved[2] samples (n=105) using either a Dremel rotary tool outfitted with a 1mm thick diamond blade or a jeweler's saw. In the case of the former, a flow of distilled water was run over the sample during cutting to prevent heat alteration of the microstructure due to overheating. The cut fragments were then sub-sampled using a jeweler's saw, with one portion being mounted in epoxy while the other was reserved for lead isotope (LI) analysis. For mounting, either Pace Technologies Epocast or Metkon Epocold epoxy resin was used. Mounts were then ground using 1200 grit SiC paper,

[2] Samples were selected in consultation with Prof. Aslıhan Yener. In the case of finished objects, it was generally required that the object be in a fragmentary state to be eligible – that is, nothing completely intact that may have value as a museum piece.

followed by 800 grit alumina paper. The reason for this pattern, as opposed to the usual practice of starting with a coarser abrasive and working down to finer papers is that the crystal shape and hardness of SiC allows this abrasive to aggressively remove excess epoxy with a minimum of damage to the sample. 800 grit alumina, thanks to its superior finishing characteristics and tendency to break down more readily, was then able to provide a finer surface before polishing with diamond suspension. Polishing was carried out using diamond suspensions of 9μm, 6μm, 3μm, and 1μm, and then finished with colloidal silica.

Initial observations were made using a Leitz Laborlux polarizing light microscope at the University of Chicago Anthropology Department.[3] In the case of metal samples, a second evaluation was made after etching with either alcoholic ferric chloride or Klemm's I reagent[4] to gain further information on grain size, deformation, annealing twins, and other morphologies resulting from the working process. After initial observation, all samples were re-polished and taken to the Cyprus Institute[5] where they were re-examined using a Zeiss Axio polarizing light microscope. No etching was used during this second round of observation where the primary purpose was to (a) take advantage of better-quality optics to check for features that were potentially missed previously and (b) to identify features of interest for SEM-EDS analysis.

After OM evaluation, samples were carbon coated and analyzed at the Cyprus Institute using a Zeiss Evo scanning electron microscope. Operating parameters were: HV = 20kV, iProbe

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[3] My gratitude to Prof. Mickey Dietler for generously allowing me to use his equipment and lab space.

[4] Klemm's I was typically the preferred etchant due to its slower rate of attack and its deposition of a color film, which was particularly valuable in analyzing samples with a small grain size.

[5] Special thanks to Prof. Thilo Rehren and Dr. Brunella Santarelli for the use of the facilities at the Cyprus Institute and their patient guidance.

= 1nA, Working Distance = ~8.5mm. Before each session, SRM MBH 36X SP1 A[6] was analyzed via EDS using three 1x1mm area analyses that were then averaged together to evaluate consistency between analytical sessions. To check the capability of the EDS unit for measuring low concentrations of tin, a single set of measurements was taken from SRM MBH 31X 7835-8 A (Table 6-1). All images taken during SEM analysis were backscattered electron (BSE) images, unless otherwise noted.

| MBH 36X SP1 A | Analysis 1 | Analysis 2 | Analysis 3 | Analysis 4 | Analysis 5 | Analysis 6 | Analysis 7 | Analysis 8 | Analysis 9 | Analysis 10 | Average | Certified Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mn | 0.04 | 0.09 | 0.13 | 0.11 | 0.09 | 0.13 | 0.1 | 0.18 | 0.13 | 0.09 | 0.11 | 0.084 |
| Fe | 0.5 | 0.46 | 0.51 | 0.47 | 0.46 | 0.49 | 0.49 | 0.45 | 0.48 | 0.46 | 0.48 | 0.45 |
| Co | 0.08 | 0.06 | 0.07 | 0.09 | 0.04 | 0.05 | 0.09 | 0.07 | 0.04 | 0.09 | 0.07 | 0.057 |
| Ni | 8.68 | 8.72 | 8.73 | 8.51 | 8.65 | 8.68 | 8.56 | 8.64 | 8.41 | 8.66 | 8.62 | 8.33 |
| Cu | 84.21 | 83.94 | 83.99 | 84.57 | 84.28 | 84.43 | 84.29 | 84.2 | 84.44 | 84.18 | 84.25 | 84.9 |
| Zn | 0.38 | 0.46 | 0.53 | 0.31 | 0.46 | 0.3 | 0.33 | 0.48 | 0.42 | 0.49 | 0.42 | 0.344 |
| Sn | 6.01 | 6.24 | 5.81 | 5.84 | 5.87 | 5.83 | 5.96 | 5.95 | 5.99 | 5.91 | 5.94 | 5.75 |
| Sb | 0.02 | 0.01 | 0.07 | 0.03 | 0 | 0.01 | 0.02 | 0.02 | 0 | 0.02 | 0.02 | 0.018 |
| Pb | 0.07 | 0.02 | 0.17 | 0.07 | 0.15 | 0.1 | 0.17 | 0 | 0.08 | 0.11 | 0.09 | 0.012 |
| MBH 31X 7835-8 | Analysis 1 | Analysis 2 | Analysis 3 | Average | Certified Value | | | | | | | |
| Ni | 0.08 | 0.13 | 0.15 | 0.12 | 0.158 | | | | | | | |
| Cu | 69.07 | 68.6 | 68.89 | 68.85 | 69.93 | | | | | | | |
| Zn | 25.28 | 25.45 | 25.41 | 25.38 | 24.83 | | | | | | | |
| As | 0.29 | 0.39 | 0.24 | 0.31 | 0.143 | | | | | | | |
| Ag | 0.53 | 0.5 | 0.4 | 0.48 | 0.463 | | | | | | | |
| Sn | 0.45 | 0.43 | 0.42 | 0.43 | 0.516 | | | | | | | |
| Pb | 4.3 | 4.51 | 4.49 | 4.43 | 3.15 | | | | | | | |

Table 6-1: Bulk analyses of standards MBH 36X SP1 A and MBH 31X 7835-8 A. Each analysis was derived from an area of 1x1mm.

For bulk compositional analysis, every sample was subjected to three 1x1mm areal measurements, the results of which were averaged for a final composition. Where intergranular corrosion was too extensive to allow for reliable analysis using this method, bulk measurements were taken by performing area analyses on several grains of intact metal to cover a comparable area. While this is broadly acceptable in cases where the metal is likely to be more

[6] SRM refers to "Standard Reference Material" which is a sample of a material with a known composition established through a series of interlaboratory tests. These materials are used for calibrating equipment as well as evaluating instrument stability and reliability of results between analytical sessions.

homogeneous, such as in the case of annealed bronzes or largely pure copper, in situations such as as-cast bronzes, where there is significant heterogeneity, the values for tin will often be elevated due to preferential corrosion of low-tin core material. In addition, since sulfide inclusions tend to be found along grain boundaries, which often serve as conduits for corrosion, sulfur values may also be slightly higher.

Point analyses were taken of minor phases in each sample. In the case of metals, this was typically a variety of copper sulfides accompanied by less common oxide and metallic inclusions. For slags, point analyses were used to identify specific mineral phases via observation of stoichiometric composition based on at% values for each element. While XRD would be a more reliable method, we decided that for the purposes of the current project, the combination of OM observations alongside compositional data would be sufficient. In addition, an effort was also made to characterize metallic inclusions insofar as was possible. Due to slag heterogeneity, there is significant room for variation outside the reported values (Hauptmann, 2007, p. 29; Rademakers and Rehren, 2015). Compositions from point analyses were determined by taking the mean of three measurements of each phase.

Finally, in several cases it was deemed worthwhile to analyze mineral inclusions trapped in samples or on their outer edges as a means of determining the mineral composition of the surrounding burial environment as representative of the original floor material. In most cases, this was done via point analysis of discrete features within each mineral, as well as areal analysis of the bulk material. As with the slag analyses, identification of minerals was carried out based on stoichiometry. Because our interest in these materials stems from the nature of the entrapped inclusions and their potential reflection of the ores used in the smelting process, the values reported are the result of individual points, as opposed to the averaging strategy taken with other materials. Therefore, the results of these analyses should be understood only as qualitative indicators.

## 6.2 Results

### *6.2.1 High-tin Bronze*

At 20.41% (n=20) of the study assemblage, high-tin bronze (>6 wt.% Sn) constitutes the most abundant class of material. Within this category, there are seven amorphous fragments, one awl, four shafts, two pin/needles, one rim fragment, one crescent, and three sheet fragments. As an initial observation of this distribution, the finished objects are characterized by a mixture of utilitarian and decorative items, with needles and awls falling under the heading of "tools," while shafts are likely broken fragments of either needles or awls. Objects such as the crescent were probably part of a jewelry assemblage (Siegelová and Tsumoto, 2011, p. 293), while sheet fragments are liable to have been cladding for a variety of different objects, as is attested archaeologically and textually (Yener, 2014, 2007, p. 154). In the case of what I have termed a "rim," it seems we are dealing with a fragment of what may have once been a vessel of some sort, which could easily fit into categories of either utilitarian or decorative.[7]

Figure 6-1: Fragment AT19926. Black objects on the surface are fragments of charcoal originally embedded in the surface of the metal. © 2020 Alalakh Archives

[7] Realistically, defining any of these objects strictly as utilitarian or decorative is problematic, in as far as their compositions would have made them both mechanically useful as well as visually

The amorphous fragments and “flow” may be variably defined as casting spill and/or alloying waste. Because molten metal tends to assume a relatively round droplet form when falling through air due to surface tension, the smaller more spherical fragments can be reasonably considered to be casting spill – that is, material that was blown out of a sprue during casting by escaping gas and solidified before hitting the ground. Larger fragments may be pieces of bronze that were agglomerated in a crucible, or fragments of metal that failed to sink to the bottom of a furnace before the end of a smelting operation[8]. Either possibility is suggested by the presence of large fragments of charcoal embedded in the corrosion crust of all such pieces, but especially AT19926 (Figure 6-1). Two samples, AT4007 and AT0569, the former being a flow of metal and the other being another amorphous fragment, are remnants of alloying material and

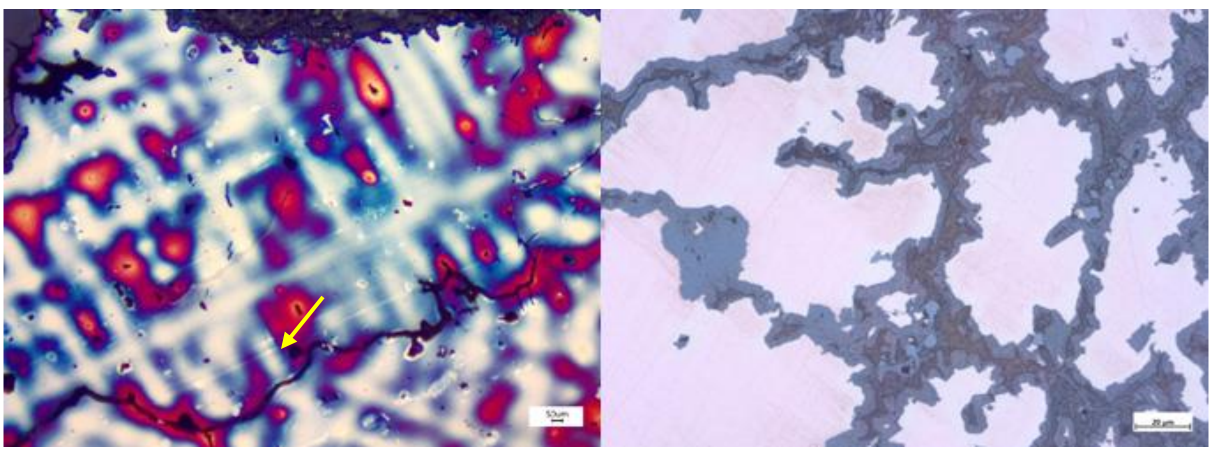

Figure 6-2: At left – AT25650. General view showing the dendritic microstructure as enhanced by Klemm’s I etchant. The white areas at the copper-rich cores of the dendrite arms (yellow arrow) with increasing Sn content moving through purple and red to light yellow. In this example, the large grain size and poor dendrite definition suggest a relatively slow cooling process (scale bar = 50μm). 40x mag. Plain light. At right – AT21374 – Detail showing grain coring with the pink areas being more copper rich, while the whitish areas at the edge contain more tin. The mottled brown and dark gray areas are corroded α+δ eutectoid while the medium gray globules are copper sulfides. The gray rim surrounding the grains is corroded δ phase (scale bar = 20μm). 500x mag. Plain light.

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striking. There is, furthermore, the question of whether we should classify social signaling through material as a utilitarian exercise.

[8] See below for a discussion of the potential evidence for direct bronze smelting at the site.

processes related to speiss found during the excavations. This topic will be discussed in further detail below.

In almost all cases, these fragments exhibit an as-cast dendritic structure with substantial coring and intergranular α+δ eutectoid (Figure 6-2). Cored microstructures are a result of thermodynamic disequilibrium wherein a material with a higher melting point begins to freeze, excluding the material with a lower melting point. As this process continues, the solidifying material becomes increasingly tin-rich, up to around 14 wt.% Sn (Scott, 1991, p. 25). At this point, there is more molten tin than the α phase is able to absorb in its current crystalline structure, resulting in the formation of a secondary δ-phase at the grain boundaries (Saunders and Miodownik, 1990, p. 279). Depending on the composition of the original melt, in some instances (i.e. Figure 6-2 - Right) after the formation of an initial layer of δ-phase the remaining intergranular space is infilled by α+δ eutectoid.

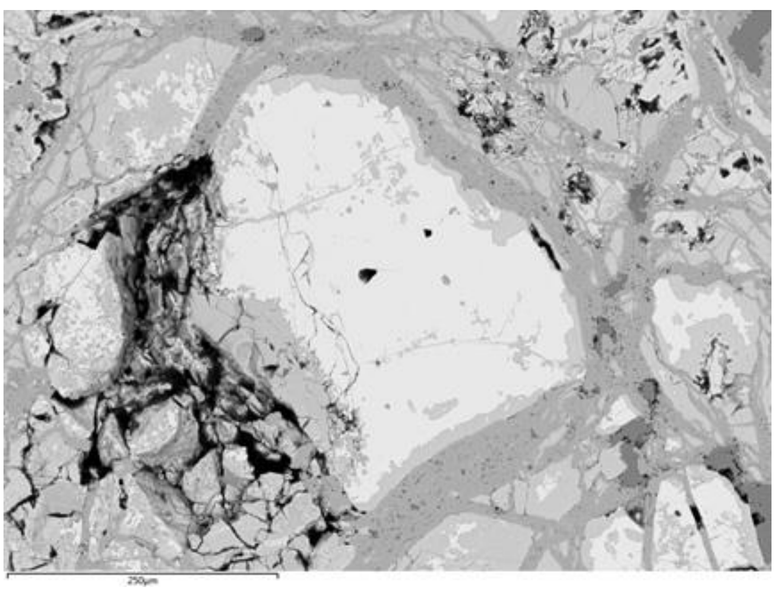


Figure 6-3: AT0569 - BSE image of preserved metallic phase of the sample (bright white grain at center). There is, unusually, no phase differentiation, suggesting a homogeneous composition of 32-33 wt.% Sn.

With AT4007 and AT0569, we are faced with two metal fragments that have significant implications for our understanding of the production of tin bronze. Several hypotheses have historically been put forward for methods of alloying copper and tin, including direct alloying of the two metals, the addition of cassiterite to molten copper, as well as the co-smelting of copper and tin ores in a single furnace to produce either a bronze of largely uncontrolled tin content, or what might be termed a "master alloy" with a high tin content that could be used in a similar manner to pure tin metal (Muhly, 1985, p. 280; Rademakers et al., 2018a, pp. 519–520; Rademakers and Farci, 2018; Yener and Özbal, 1987, pp. 221–222). Potentially representing a globule of master alloy AT0569 is composed almost entirely of δ-bronze (65% Cu, 33% Sn, 0.6% As) (Figure 6-3), representing an excellent complement to the Sn-rich crucible slags found on site.

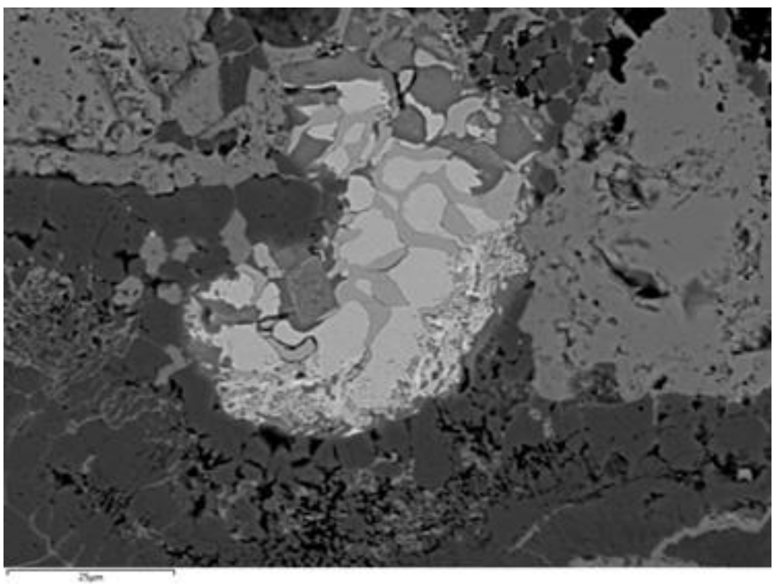


Figure 6-4: AT4007 - Globule at upper surface of sample. The light gray phase is preserved metallic bronze with the composition provided in the text. The medium gray phase between those islands is 60% Cu, 30% As, with Sb and Sn. The white phase at the edge of the prill is 16% Cu, 23% As, 44% Sn, 3% Sb, and 6% Pb.

In contrast with the seemingly straightforward character of AT0569, AT4007 represents a more complex set of circumstances. At the upper surface, was an intact globule (Figure 6-4) of metal with a primary composition of 0.4 wt.% Fe, 0.5% Ni, 58% Cu, 4% As, 34% Sn, and 1% Sb, that was also in association with large fragments of what may be loosely termed pseudo-mushishtonite (Table 6-2), due to its similar composition to the ores exploited at Mushishton in Turkmenistan ($(Cu,Zn,Fe)Sn(OH)_6$) (Garner, 2015). Further down in the sample were eutectic structures (Figure 6-5) with a clear surrounding diffusion gradient, suggesting that these were partially absorbed fragments of material that had been added to the melt. While the copper content should be considered an overestimation relative to the original composition of this material, the current bulk composition is 67.98 wt.% Cu, 16.28% As, 11.17% Sn, 3.58% Sb, and 0.98% Pb. When viewed alongside the elemental makeup of speiss samples from the site, with emphasis on the elevated contents of As, Sb, and Pb and to a lesser extent Ni, there is a strong case for the use of Sn-rich speiss and associated high-Sn bronze materials in the local production of high-Sn bronze.

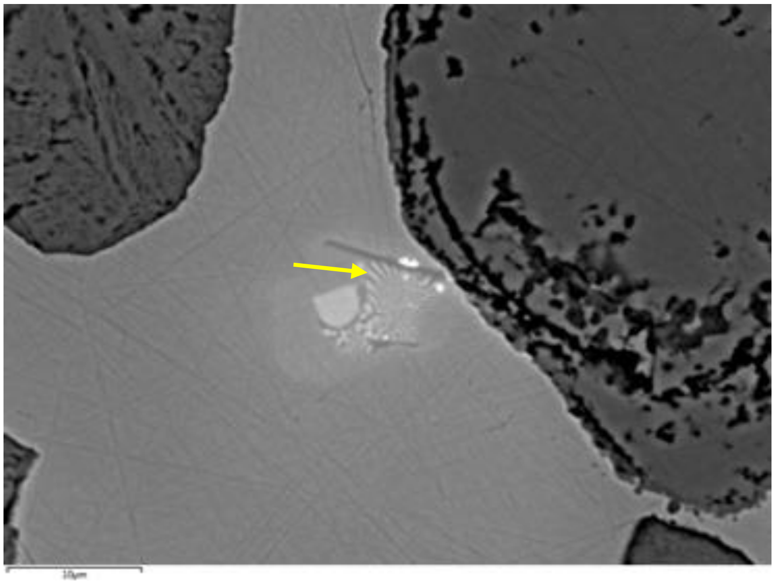


Figure 6-5: AT4007 - image of eutectic (banded, fingerlike – yellow arrow) structure with high As, Sn, and Sb contents. The light halo surrounding this area is the diffusion gradient resulting from the melting of the original fragment and its inclusion into the Cu matrix.

Microstructurally, most high-Sn bronze objects show evidence of extensive working. Small, equiaxed grains are the norm, all objects display twinning, and many display strain lines indicative of a final round of cold working to impart hardness (Figure 6-6 and Figure 6-7). Of these objects, four out of nine also display significantly deformed grains. The presence of strain lines in association with evidence of prior annealing is indicative of a final stage of cold working that can be generally interpreted as a final step to

| Pseudo-Mushistonite | Analysis 1 | Analysis 2 | Analysis 3 | Analysis 4 |
|---|---|---|---|---|
| O | 70.06 | 70.21 | 70.75 | 70.92 |
| Al | 0.43 | nd | nd | nd |
| Si | 0.63 | 1.58 | 0.93 | 0.73 |
| P | 0.18 | nd | nd | 0.21 |
| S | 0.29 | nd | 0.23 | 0.37 |
| Fe | 3.57 | 1.76 | 2.44 | 3.94 |
| Co | nd | 0.25 | nd | nd |
| Ni | nd | 0.28 | nd | nd |
| Cu | 3.62 | 3.52 | 3.36 | 2.4 |
| As | 3.89 | 3.16 | 3.34 | 3.99 |
| Sn | 17.33 | 19.05 | 18.95 | 17.44 |
| Pb | nd | 0.18 | nd | nd |

Table 6-2: SEM-EDS results for pseuo-mushishtonite.

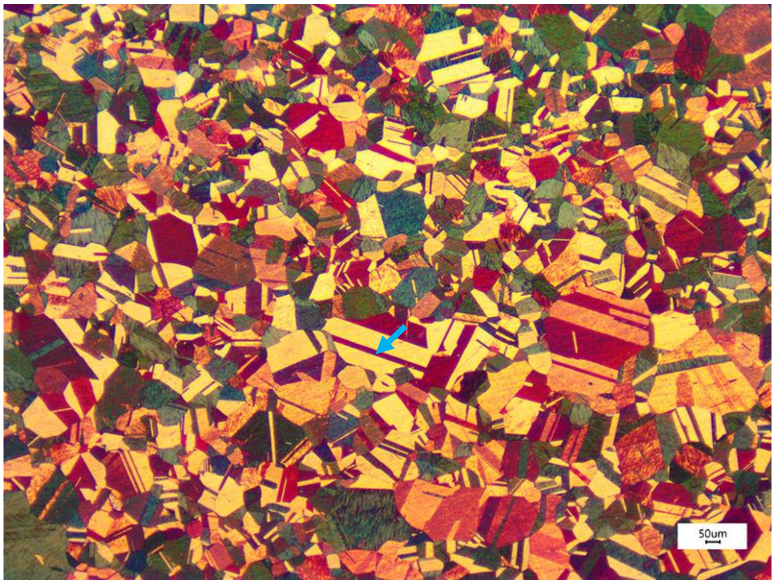



Figure 6-6: AT18494 – General view showing equiaxed grains with extensive annealing twins (blue arrow). Klemm's I etch. 100x mag. Plain light.

increase the hardness and durability of an object (De Ryck et al., 2003, p. 587; Dungworth, 2013). As the repeated application of force causes slippage occurs along crystallographic planes, adjacent planes impinge on one another preventing further deformation and imparting increased hardness, making an object more mechanically durable (Rostoker and Dvorak, 1990, pp. 12–25). In the case of sheet fragments, strain lines could originate from a final stage of hammering to fit sheet metal around a core or could be left over from the manufacturing process if ductility was not an important feature of the finished sheet. The generally small grain size, particularly seen in most awls and sheet fragments, is a further indication of a substantial degree of cold working. This phenomenon arises as cold reduction causes stress accumulation in the crystal lattice of individual grains. When exposed to elevated temperatures that allow for the movement of atoms, points of stored stress act as nuclei for grain recrystallization which is initiated by the release of energy stored in features created by the working process, such as strain lines (Humphreys and Hatherly, 2004, pp. 19–20; Rostoker and Dvorak, 1990, pp. 25–34). The degree of disturbance to the atomic lattice (i.e. the extensiveness of cold working) is directly related to the size of recrystallized grains, with more extensive disturbance being related to a smaller grain size as well as lower annealing temperatures (Rostoker and Dvorak, 1990, pp. 28–31; Scott, 1991, p. 9).[9] In a similar fashion annealing twins (Figure 6-6), which appear as bands with largely parallel lines, are another method for the release of excess energy in crystal lattices, though the exact mechanisms of their formation remain unclear (Humphreys and Hatherly, 2004, pp. 261–267).

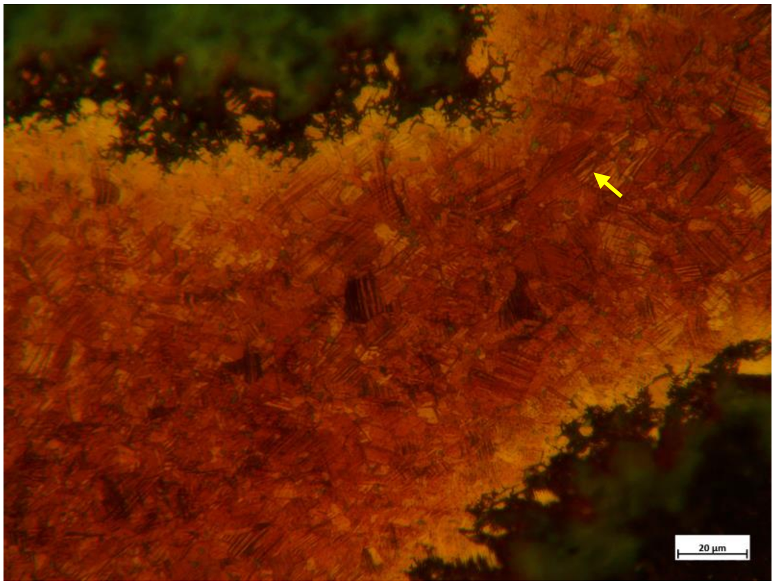



Figure 6-7: AT8037 - Detail showing heavily deformed equiaxed grains with ubiquitous strain lines (fibrous structures, yellow line) and deformed annealing twins, indicating a significant degree of final deformation. 500x mag. plain light. $FeCl_3$ etch.

Despite this broad generalization, the high-tin bronzes do show a certain degree of variability in how these features manifest. Among the awls, shafts, and pins, all of which are likely to have undergone essentially the same working process since they are practically similar tools, we see substantial variance in the degree of final grain deformation. This is particularly significant for the hardness of the final object. Looking at a generic 8% Sn bronze, when it undergoes a 50% reduction in thickness during cold working it will attain a hardness of ~195 $H_B$[10] . Once annealed, the same material will have a hardness of 82 $H_B$ (Dungworth, 2002; Scott,

[9] In reality, grain size is determined by a variety of factors including annealing time, temperature, and alloy composition. In addition, the cooling history of the original cast can have an impact on maximum grain size in as far as stresses induced during rapid cooling can limit the maximum grain size by up to 10%. Generally speaking, however, increased degrees of cold working decrease both the size of recrystallized grains as well as the temperature needed to achieve recrystallization.

[10] For reference, this is harder than an annealed 0.45% C steel.

1991, pp. 82–83).[11] As such, in heavily worked objects such as AT8037 (Figure 6-7) or AT19158, they are likely to be significantly harder than less extensively worked examples such as AT7288 (Figure 6-8), AT4318, AT21778, AT21332, or AT21743. Looking at Figure 6-7 and Figure 6-8, the former being at 500x magnification and the latter at 50x, the clear difference in grain size immediately makes apparent the different working history of these two needles. While the highly stressed structure of AT8037 can be taken to indicate a significantly greater hardness, the larger grain size of AT7288 shows its less intensive cold working history (Humphreys and Hatherly, 2004, p. 221). Though they may both be classed within the same object type, their functions may have been quite different.

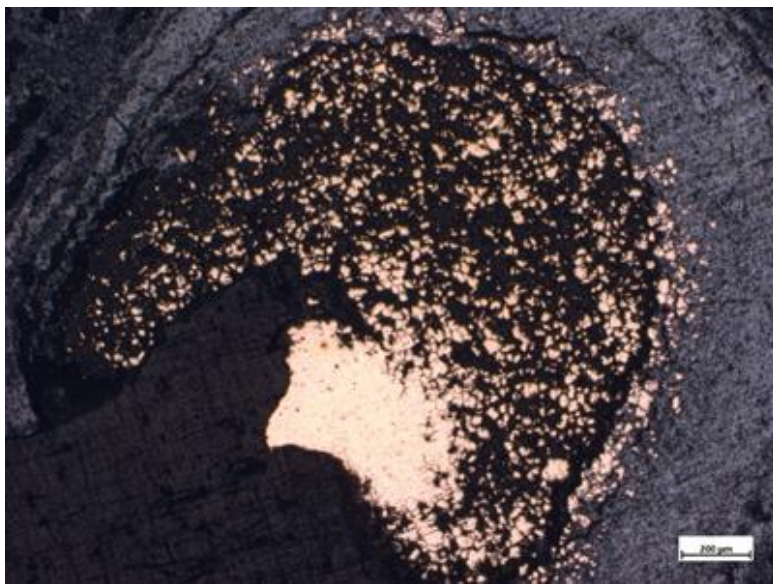


Figure 6-8: AT7288 – General view showing large, equiaxed grains. Intragranular corrosion has revealed a minimum of strain lines and a few annealing twins. 50x mag. plain light.

Based on macroscopic observation the sheet/rim fragments seem to represent several different classes of material. AT4148 and AT8904 are most likely to be decorative in nature, the former appearing as though it may have been a cladding, while the latter has an interesting stamped pattern. For AT20433 it is difficult to propose an identification, other than it seems to have been two strips wound together. Whether they were meant to be a tool or something else is not immediately clear. Finally, AT4113 seems to have

[11] Somewhat less hard than cold worked copper (100-120 $H_B$).

been part of a vessel rim or a simple decorative edge. In all cases except AT4113, we see evidence for extensive deformation including small grain size, slip lines, and grain deformation. This is likely related to the working process where the production of copper sheet requires repeated cold working and annealing to avoid embrittlement. AT4113 is unique in this category, however, in that it has an unusually large grain size with no strain lines and a moderate density of annealing twins. This suggests a long anneal at relatively high temperature or could suggest limited cold reduction <10% (Rostoker and Dvorak, 1990, p. 28).

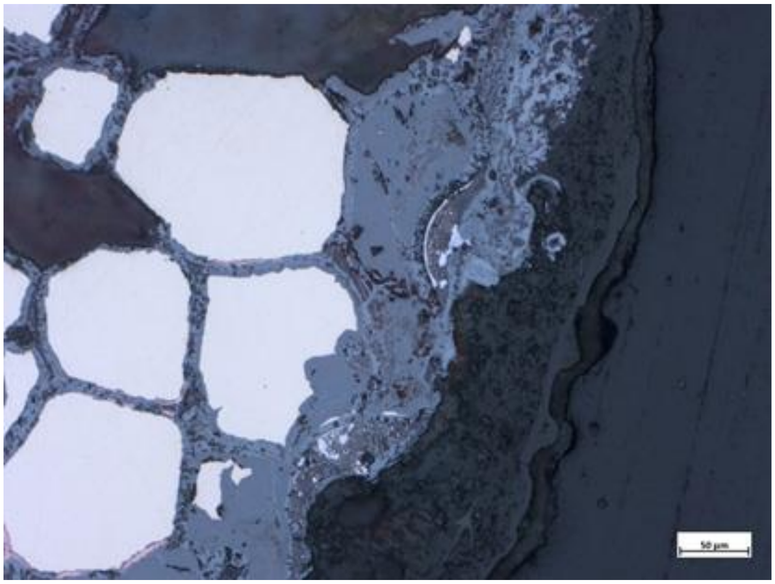


Figure 6-9: AT4113 – Detail of part of the outer margin of the sample. The silver and mottled scalloped regions are primarily δ phase accompanied by α+δ eutectoid. 200x mag. Plain light.

A clue to this situation can be seen at the outer margins of the sample (Figure 6-9). The regions occupied by δ (silver, gray) and α+δ eutectoid (mottled brownish, immediately adjacent) represent zones of significant tin enrichment compared to the primary α phase (~13 wt.% Sn). There are three possible explanations for the presence of this form. First, pure tin could have been applied to the outside of the vessel via either wiping molten tin (~232°C) onto the surface, or by dipping in a bath of molten tin at around 260°C. In order to achieve the observed microstructure this would need to have been overheated beyond about 520°C, with increasing temperature and duration quickly resulting in its complete absorption (Meeks, 1993, pp. 254–

256). The second possibility is reduction of cassiterite directly on the surface of the object at around 750°C in a reducing atmosphere. The third option involves exploitation of a phenomenon known as tin-sweat (Meeks, 1993, p. 263). Since the functional (as opposed to theoretically ideal) solubility limit of tin in copper is around 14 wt.% Sn (Scott, 1991, p. 25), alloys at and above this composition experience a segregation of tin from the primary α-phase as a secondary δ-phase as a casting cools. Because the δ phase remains liquid at lower temperatures, it tends to migrate toward the outer surface of the object due to capillary action along grain boundaries, the heat gradient toward the outer surface, pressure from the release of dissolved gas. What this achieves, in effect, is an indirect form of tinning, though secondary working processes will tend to destroy this coating (Meeks, 1993, p. 261). Between the large annealed grain size and annealing twins which indicate high temperature and a preliminary working regime, the retention of surface eutectoid, and the fact that tin sweat is usually associated with as-cast objects, direct reduction of cassiterite on the surface seems the most probable option.

### *6.2.2 Low-Tin Bronze*

At 12.24% (n=12) of the total assemblage, low-tin bronzes (<6 wt.% Sn) are the fourth most common variety of material. This group is composed of four amorphous fragments, three awls, one chisel, one pin/needle, one point, one rim, and one beer strainer, such as those typically affixed to the end of a straw for drinking (Maeir and Garfinkel, 1992). Low-tin bronze seems to be used more frequently for tools, with fewer decorative objects than among the high-tin bronzes.


Figure 6-10: AT4101 – General object photo showing obverse side. © 2020 Alalakh Archives

From the amorphous fragments, several pieces are noteworthy. First, AT4104 (Figure 6-10), a small roughly 3cm diameter disk with a wedge amounting to about ¼ of its probable original size cut out. The upper face of this disk (not pictured) is marked by numerous gashes from attempts at cutting it with a chisel. Microstructurally, this object has an as-cast dendritic structure, large numbers of degassing voids, and a high density of copper sulfide inclusions. Aside from deformation around a cut in the upper surface of the mounted sample, there are no further signs of working or thermal treatment, meaning that this disk was originally cast to this shape. Whether it should be considered a crude ingot or some form of currency[12] is not clear, though the missing ¼ makes it tempting to speculate that it represents the latter.

Though both appear to be relatively non-descript, AT4309 and AT8040 raise further questions about alloying practice in addition to providing important evidence for the identification of workspaces. Upon initial observation, both fragments exhibit a thoroughly dendritic structure with phase segregation typical of as-cast bronzes. In some areas, large masses of tin oxide ($SnO_2$) crystals are present (Figure 6-11),

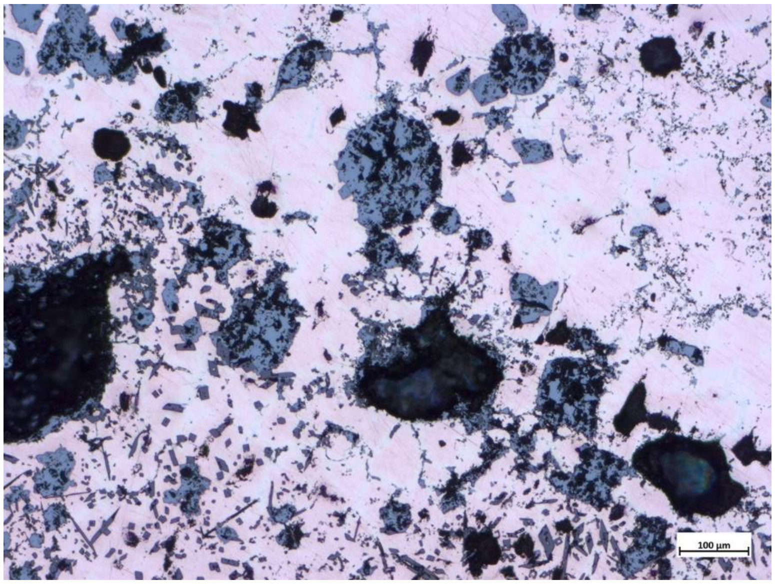



Figure 6-11: AT4309 – view contrasting oxidized (lower left corner) and unoxidized (upper right) portions of the sample. In the lower left corner, sharply angular dark gray crystals are $SnO_2$, which frequently contain a bleb of copper metal at the center. Note that the matrix between these crystals, particularly at the extreme extent of the corner where they are more dense, is much pinker than the upper right. In the upper right corner, a web of light almost white tin-rich metal can be seen outlining the grain structure. 100x mag. Plain light.

[12] Side-stepping the question of whether this distinction is even useful for the LBA, for now.

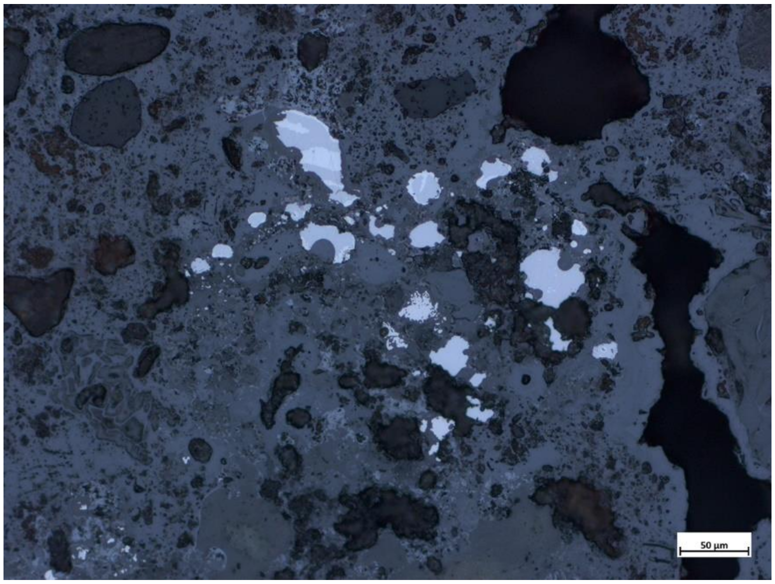



Figure 6-12: AT4109_2 – Illustrative example of prills of whitish epsilon (ε) and gray eta (η) bronze from a sample of workshop floor (see below). In addition to being associated with AT4309 and AT8040, this material also frequently appears as a component of some crucible slags. 200x mag. Plain light.

typically accompanied by a concomitant depletion in the amount of tin in the surrounding area. This, along with the morphology of the tin oxide crystals – forming as a eutectic with copper metal (see; Klein 1965) – indicates that these formed as a result of the molten bronze being exposed to an oxidizing atmosphere, as opposed to their presence being related to the addition of cassiterite to molten metal (Rademakers and Farci, 2018; Renzi and Rovira-Llorens, 2016; Vernet et al., 2019). Both samples exhibit prills of ε and η bronze (~40 and 85 wt.% Sn, respectively) (Figure 6-12), which could generally be taken to indicate alloying either through the addition of a master alloy, as discussed above, or through the addition of pure tin, with these globules then being tin that alloyed with some small amount of copper but were not agglomerated into the main mass of bronze. A further possibility is that these fragments could have originated from a process of co-smelting or cementation, resulting in a variety of unagglomerated prills of widely varying composition (Rademakers and Farci, 2018, p. 348).[13] In

[13] This tendency has been noted in a series of smelting experiments conducted by the author which will be published in the near future.

any case, it is clear that these are indicative of local alloying of “fresh” bronze, as opposed to the recycling of small fragments of material.

Adding to this narrative is AT4048_1, another amorphous fragment of non-descript character, save for the predominance of iron hydroxides in its corrosion crust. Under OM observation, this object appears as a relatively typical globule of bronze, displaying light coring and the expected islands of interdendritic α+δ eutectoid with some unusual light gray inclusions and globules of metallic iron (see “Raw Copper” below for a discussion of this feature). Where the sample becomes more atypical is in the still adhering slag, containing a substantial quantity of tin oxides, and a band of free iron oxides, reminiscent in its morphology to the magnetite “skin” that forms on the outer surface of tap slags (Hauptmann, 2011, fig. 19.8; Personal

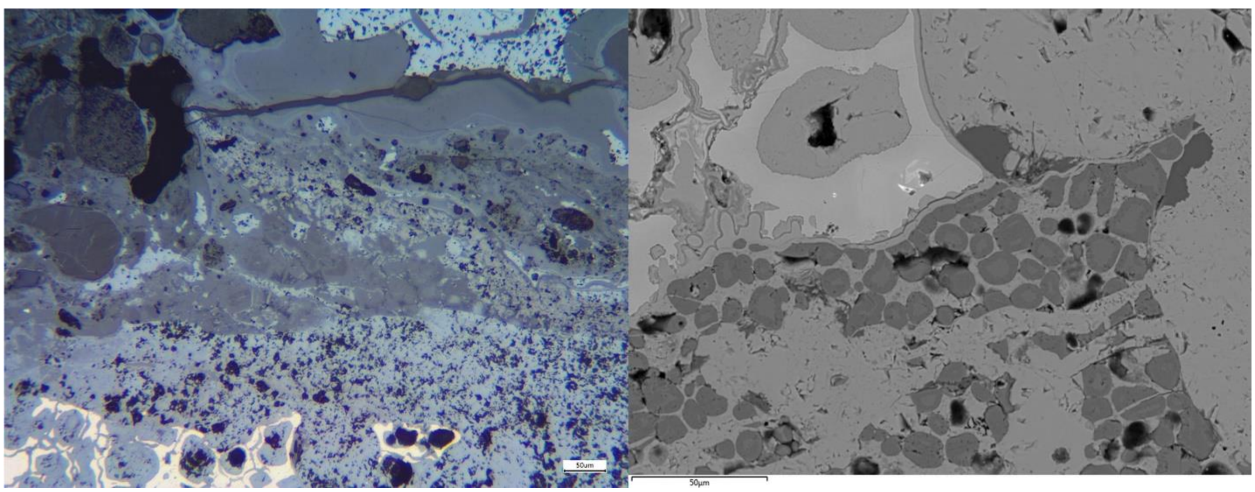


Figure 6-13: AT4048_1 – Left: OM image showing layering of the oxide skin (greenish-gray) overlying a roughly triangular shaped region of remnant slag (zoned angular grains at center). This area was revealed after re-polishing this sample following my visit to the Cyprus institute, so SEM-EDS results for the slag are unavailable. They are similar in morphology and appearance to the forsteritic grains seen in some smelting slags. Below a layer of mixed copper and iron corrosion products is the upper surface of the metal layer where Cu-rich phases have preferentially corroded from the center of the metal crystals. The large, rounded structures at the left of the image are material incorporated into the corrosion layer post-deposition. 100x mag. Plain light. Right: BSE image of a point where the oxide skin makes contact with the upper layer of the metal. The rounded zoned grains have a composition of 55% O and 44% Fe in the darker outer band, and a composition of 48% O and 50% Fe in the lighter core. The light angular features embedded in the metal near its interface with the oxide layer (roughly center image) correspond to the “Mixed Inclusion” and Speiss in Table 6-3.

| Mixed Inclusion | Point 1 | Point 2 | Point 3 | Point 4 |
|---|---|---|---|---|
| S | 1.36 | 0.11 | 1.11 | 0.19 |
| Fe | 1.33 | 0.37 | 0.72 | 2.76 |
| Cu | 78.37 | 89.01 | 79.71 | 66.9 |
| As | 4.19 | 0.99 | 4.12 | 10 |
| Ag | 2.61 | 0.23 | 1.27 | 10.14 |
| Sn | 12.15 | 9.28 | 13.06 | 10.02 |

| Speiss | Point 1 | Point 2 | Point 3 | Point 4 |
|---|---|---|---|---|
| S | 0.16 | 0.12 | nd | 0.11 |
| Fe | 44.08 | 36.92 | 40.2 | 27.64 |
| Ni | nd | 0.55 | 0.21 | 0.39 |
| Cu | 15.19 | 22.4 | 19.53 | 34.13 |
| As | 40.17 | 39.72 | 39.62 | 36.15 |
| Sn | 0.39 | 0.3 | 0.36 | 1.57 |

| δ-Phase | Point 1 | Point 2 | Point 3 | Point 4 |
|---|---|---|---|---|
| Cu | 70.21 | 74.86 | 70.55 | 69.6 |
| As | nd | 2.9 | nd | 0.97 |
| Sn | 28.56 | 22.23 | 27.87 | 28.27 |
| Sb | 1.23 | nd | 1.58 | 1.17 |
| | | | | |
| | | | | |

Table 6-3: SEM-EDS spot analyses for AT4048_1. Values are presented in wt.%.

Communication, Th. Rehren 2019). The free iron oxide skin is composed of zoned grains with a core of wüstite and an outer rim of magnetite, the latter phase of which likely formed as oxygen became enriched in the melt during freezing, finally reaching a concentration sufficient to raise the oxidation state of the remaining iron. The presence of wüstite, however, is indicative of a reducing atmosphere that is not typically encountered in activities aside from smelting. Furthermore, SEM-EDS analysis revealed the presence of partially absorbed fragments of tin-bearing speiss and tin-bearing polymetallic prills (Figure 6-13, Table 6-3). Taking this suite of material into account, the presence of wüstite alongside adhered slag and in conjunction with metallic iron in the metal itself militates against a secondary processing stage. Meanwhile, the presence of speiss and related metal inclusions draws a link to that class of material, although the exact mechanics of how this mixing took place

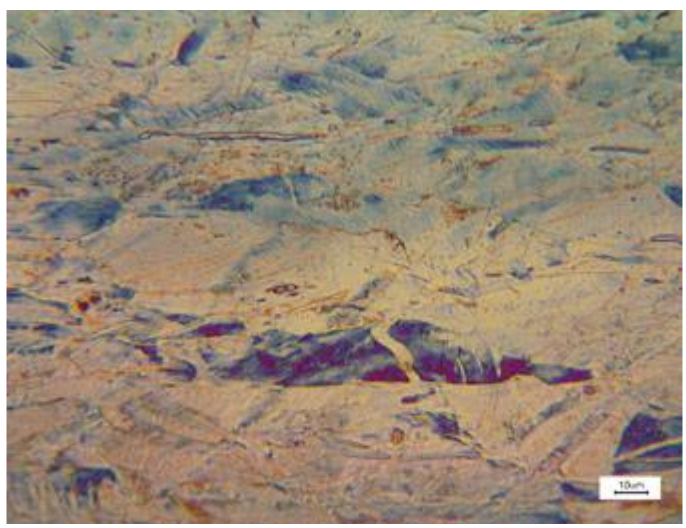


Figure 6-14: AT21536 – Detail showing extensive grain deformation in an awl. Based on degree of grain boundary definition and general grain morphology, we can give a very rough estimate of around 20% reduction for the final round of cold working. Klemm's I etch. 400x mag. Plain light.

are still not entirely clear. All things considered; this represents reasonable preliminary evidence for a direct method of bronze production in a speiss-generating process.

When considering tools manufactured from low-tin bronze, there is a fair degree of variability in working procedures. While the high-tin bronzes exhibited dense concentrations of slip lines and a relatively small grain size with only a limited occurrence of significantly deformed grains suggesting modest final working, the low tin bronzes frequently display strain lines, all show twinning, and about 50% have a significantly deformed microstructure (Figure 6-14). Among the awls, the point, and chisel, grain deformation is significant and recrystallized grain size is small. This suggests multiple rounds of cold working and annealing, with the final

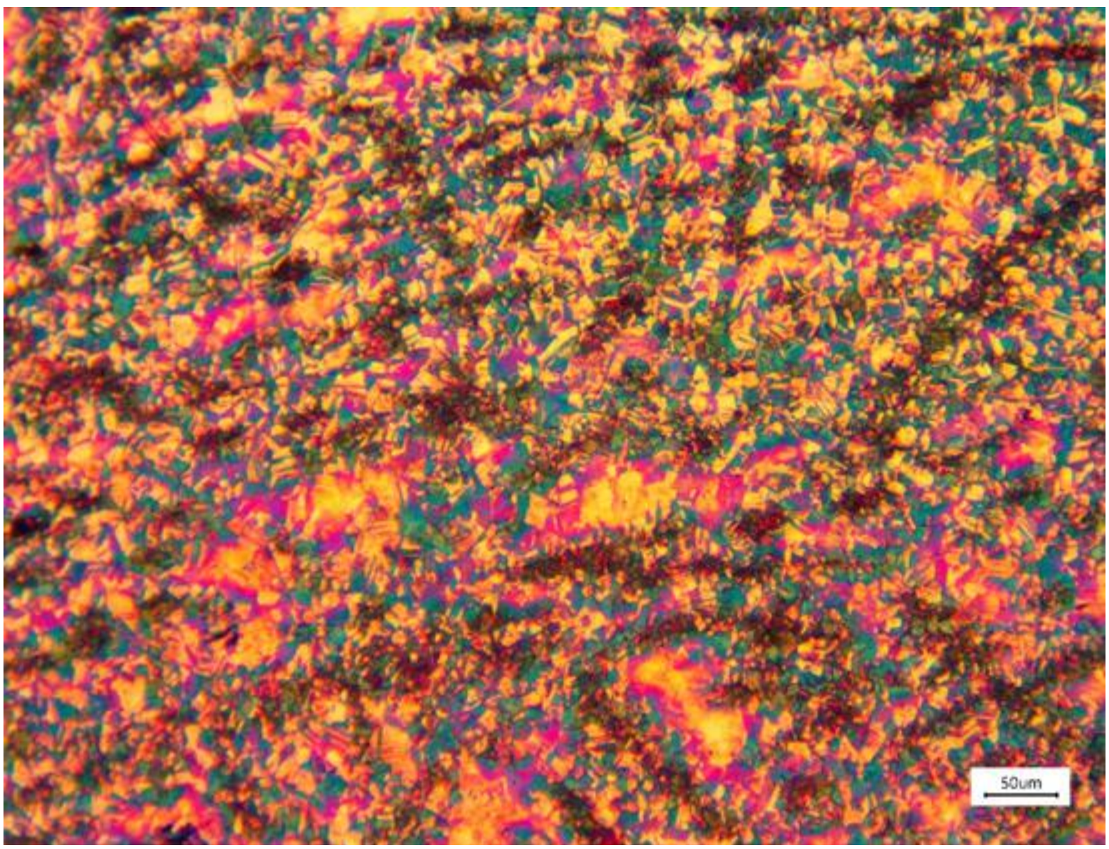


Figure 6-15: AT20450 – General view of microstructure at posterior end of the blade fragment showing equiaxed grains and annealing twins. Dark bands are areas of lower-Sn concentration where higher levels of retained stress and compositional differences have allowed deeper etching. Klemm's I etch. 100x mag. Plain light.

heavily cold worked state imparting a significant increase in hardness. The remaining three objects – one awl, a needle, and a strainer – lack strain lines. This could be taken to suggest that the archaeological classification of a robust pointed metal object as an awl was incorrect, since it was not given a final stage of work hardening. The needle and strainer, not being objects meant to endure significant mechanical stress, were also not given this final treatment.

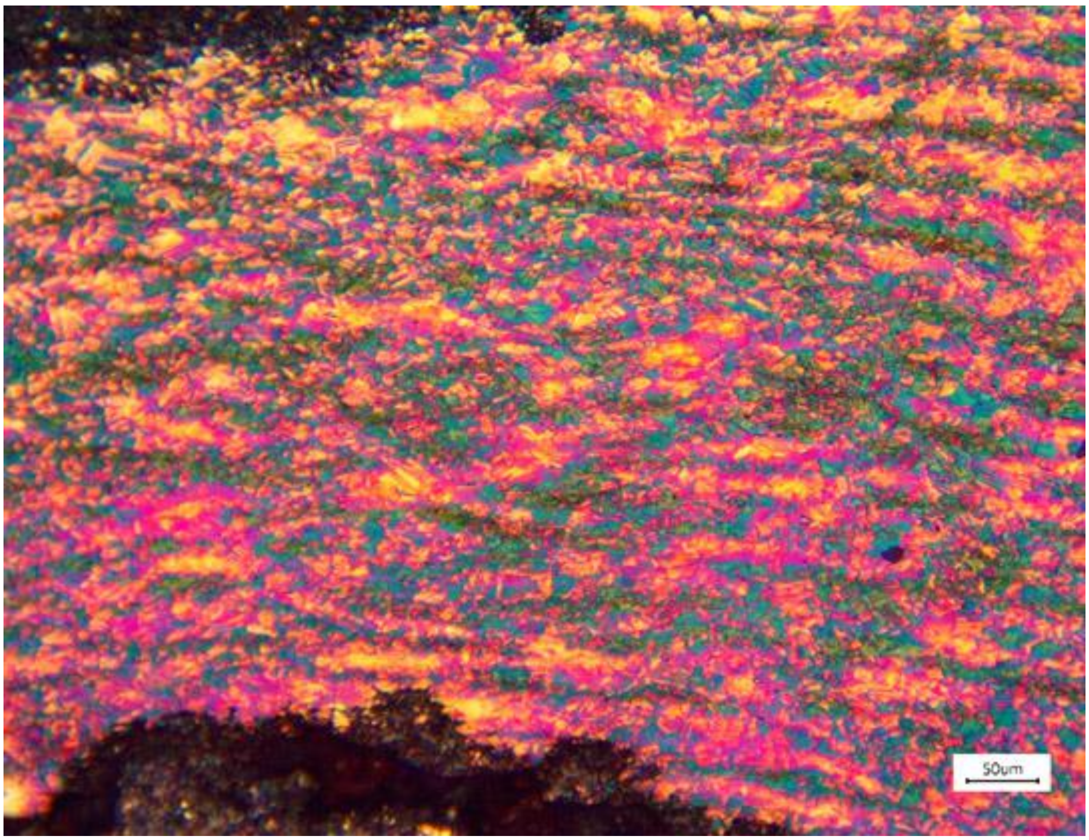



Figure 6-16: AT20450 – General view of microstructure at anterior edge of the blade. Grains are significantly more deformed and recrystallized to a smaller size than at the posterior. Klemm's I etch. 100x mag. Plain light.

When looking at the chisel (AT20450) under an optical microscope, although the structure is akin to that seen in the awls, albeit with a larger grain size, there is a notable presence of a "ghost" dendritic structure (Figure 6-15 and Figure 6-16) (Scott, 1991, p. 25). This is generally taken to indicate that coring in the original casting was extremely, however, there is a secondary implication that while temperature and duration of annealing were adequate to induce recrystallization, they were insufficient (or insufficiently repeated) for homogenization of the composition. Comparing Figure 6-15 and Figure 6-16, the significant differences in grain size between the two, as well as the degree of dendrite and grain deformation, point to a substantial difference in the extent of cold deformation of each area (Humphreys and Hatherly, 2004, pp. 220–221). Though predictable for a tool such as a chisel that requires a hard and durable cutting edge, this does serve to confirm a focus on hardening the cutting edge of the tool compared to the remainder of the object.

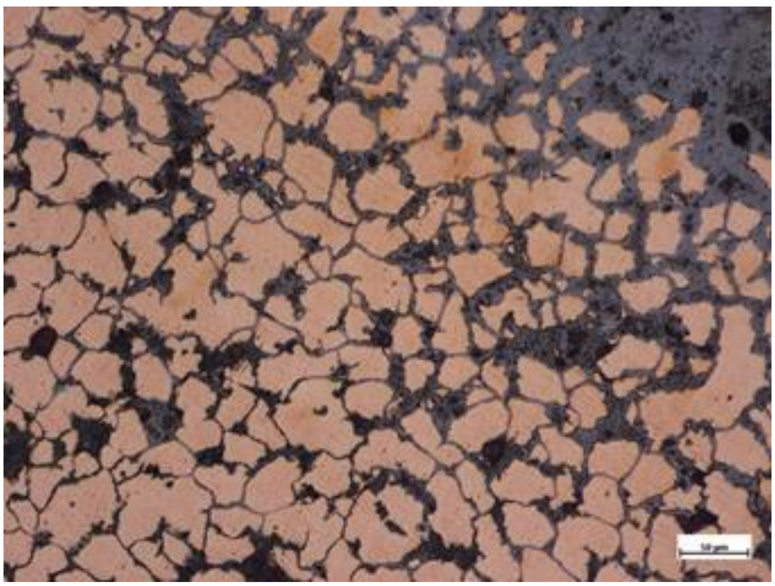


Figure 6-17: AT8002 – Micrograph showing general microstructure of the sample. Note small irregular grain size. Corroded islands of α+δ eutectoid are visible as dark brownish mottled regions between grains. Some coring is faintly visible, particularly in larger grains. Plain light. 200x mag.

The two objects composed of sheet metal, the rim (AT8002) and the beer strainer (AT21454), are quite different in their microstructures. AT8002 displays a recrystallized microstructure with an irregular grain shape that, though it approaches an equiaxed structure, is typically interrupted by islands of corroded α+δ eutectoid (Figure 6-17 and Figure 6-18). This is particularly unusual since the composition of the α phase of this object is 5.8 wt.% Sn, which is well below the saturation point of tin in copper (~14 wt.% Sn) and should allow for its ready dissolution under annealing conditions. Given the partially recrystallized grains accompanied by indications of remnant coring in BSE imagery we are left to conclude that this was carried out under circumstances of

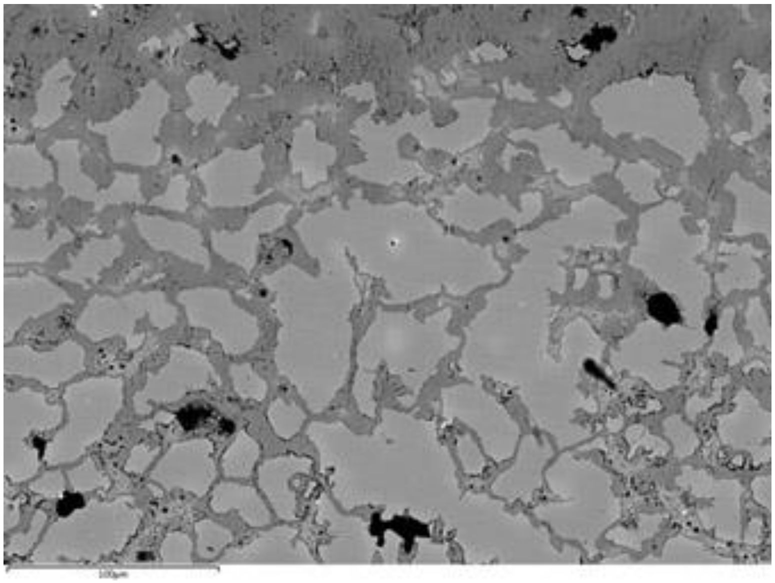


Figure 6-18: AT8002 – BSE image showing relict coring in grains. Light mottled areas between grains are corroded α+δ eutectoid, while white points are typically lead or lead oxide inclusions. Light areas at the edge of grains are remnant coring

relatively low temperature and/or short duration (Philip et al., 2003, pp. 83–84). Looking then at the copper sulfide inclusions, which typically undergo deformation during cold working and annealing, but in this case have largely retained their original shape, we can also suggest that the extent of overall deformation was not terribly great. While these inclusions can return to their original shape as seen with AT4113 (Figure 6-9), the limited degree of annealing indicated here by other evidence appears insufficient to have caused this. A possible conclusion to draw here is that this piece was cast to a relatively thin thickness, given a single limited round of cold working and shaping, and then annealed.

The beer strainer, AT21454 (Figure 6-6), is a rather typical piece of sheet metal, the treatment of which is similar to AT4113. Grains are large and equiaxed with abundant annealing twins. All this goes to indicate modest cold working, followed by a thorough annealing period leading to the large grain size, probably to facilitate the final shaping and piercing of this relatively complex object.

### *6.2.3 Raw Copper*

Raw copper is defined by the substantial presence of metallic iron and copper sulfide inclusions, indicating that the metal has not been processed, or only been minimally processed,

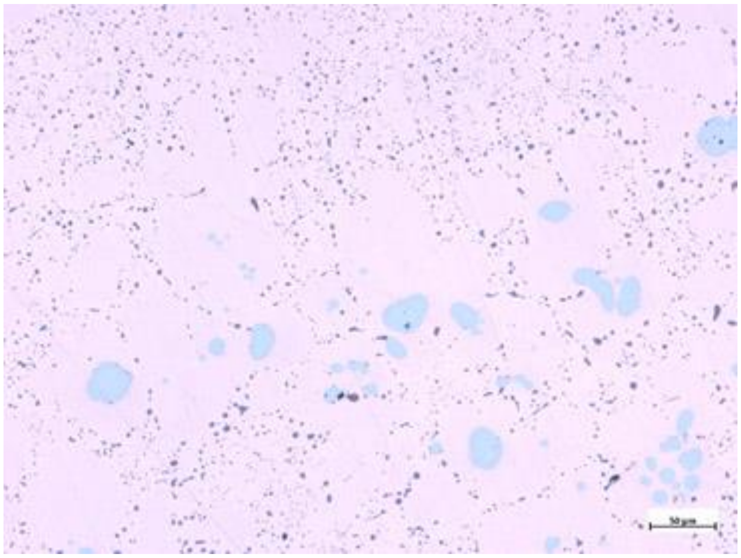


Figure 6-19: AT8686 – general view of the structure of raw copper. The dark gray eutectoid dominating the field is a mixture of copper sulfides, while the large, light gray globules are metallic iron. Toward the center of the field, strings of copper sulfides are arrayed along grain boundaries highlighting an underlying equiaxed grain structure. Plain light. 200x mag.

post-smelting (Craddock and Meeks, 1987; Merkel, 1982, p. 287). In the case of metallic iron, the more negative free energy of formation of iron oxides as opposed to those of copper means that in copper melts iron acts as an oxygen buffer to a limited extent, forming stable oxides that rise to the surface of the melt to form a slag with a variety of other silicates and oxides. The result is that in any secondary melting context, iron and other easily oxidized elements such as cobalt, nickel, and sulfur will be removed from the system to a significant degree before copper begins to oxidize. This is a simplified description of the process of selective oxidation, which forms the basis for pyrometallurgical refining, making the distinction between refined and raw metal relatively simple (Bodsworth, 2018, pp. 202–205).


Figure 6-20: AT23960 – general object photo of kohl stick. The sampled portion came from the rounded section at the left side. © 2020 Alalakh Archives

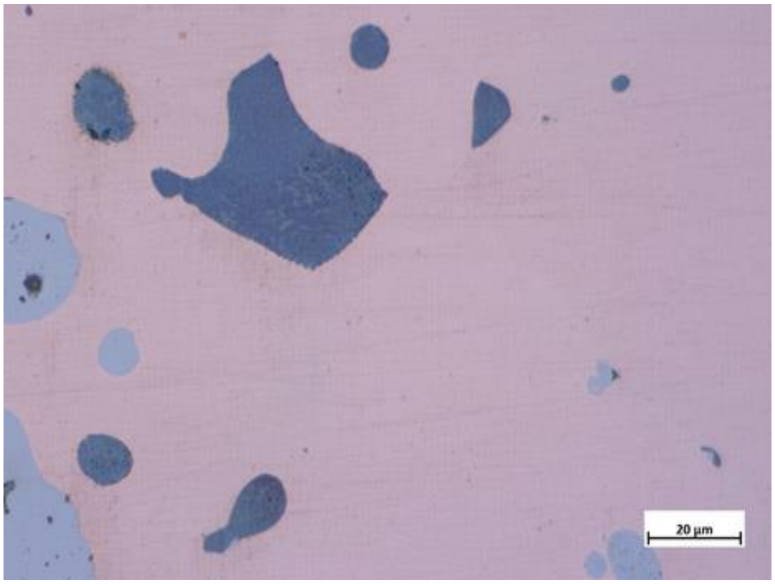



Figure 6-21: AT22853 – Detail showing bornitic inclusion (dark gray, upper left) containing lamellar chalcopyrite (yellowish) and covellite (blue). Light gray globules are metallic iron. Plain light. 500x mag.

Having laid out the criteria for defining an object as raw copper, the category represents 17.17% (n=17) of the total assemblage, with the majority (14) of these objects being amorphous fragments. As a general note, these objects should be considered *very* closely related to the HSP category, with the primary distinction that objects in the latter category still have adhered smelting slag. Microstructurally, raw copper is characterized by varying quantities of metallic iron distributed irregularly throughout the matrix, sometimes including small pockets of copper and iron sulfides. Much of the surrounding matrix is then dominated by a medium-dark gray eutectoid (Figure 6-19) composed of copper sulfides (typically a chalcocitic or bornitic composition), that will also sometimes display lamellae of iron oxides or more reduced copper sulfides (Figure 6-21). As a rule, elements aside from Cu, Fe, and S were below the detection limit in all phases of this material, with the occasional appearance of low levels (0.2 – 1 wt.%) of As, and the very rare occurrence of Sn, Ni, and Co.

As mentioned above, all but three pieces of raw copper are amorphous globules with no signs of working or processing. As for the three objects, they are a small graver-like blade, an arrowhead, and what was termed a shaft in the excavation documentation, but is most likely a kohl stick (AT23960)(Figure 6-20). In all cases, these objects contain inclusions of metallic iron,

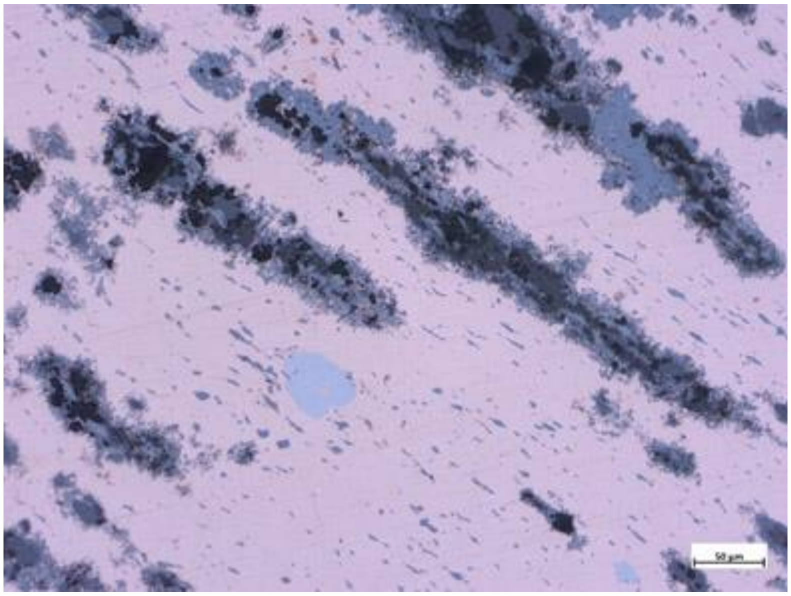


Figure 6-22: AT8666 – Detail of microstructure showing metallic iron inclusions (light gray) and heavily deformed copper sulfides (dark and medium gray). Plain light. 200x mag.

as well as substantial quantities of copper sulfides, although AT23960 contains less of both than either the arrowhead (AT8237) or the blade (AT8666). Among these objects, AT8666 (Figure 6-22) is particularly notable in terms of its elevated tin content (0.6%) in association with Ni, Co, and As (all at 0.6%), as this hints at the presence of polymetallic tin-bearing ores in the catchment of Tell Atchana. Considered alongside samples such as AT4048_1, and the association of Cu, As, Ni, and Sn in this material, the production of a so-called “natural” bronze alloy gains some currency. Within this schema, the metal for AT8666 would likely be the result of smelting ores that had been separated out for producing pure copper, but still had enough extraneous material to impart a low quantity of tin.

### 6.2.4 *Refined Copper*

Based on the discussion presented at the beginning of the section on raw copper, the material we have classed as refined copper is characterized by an absence of metallic iron incusions (translating to a bulk composition <1 wt.% Fe) and bulk sulfur below 0.6 wt.%. In the case of sulfur, this trend is somewhat softer, while in the case of iron, the division is constant. Regarding the composition of copper sulfide inclusions, the majority of are of a chalcocitic composition as in the raw copper, though a handful of non-stoichiometric mixed sulfides can

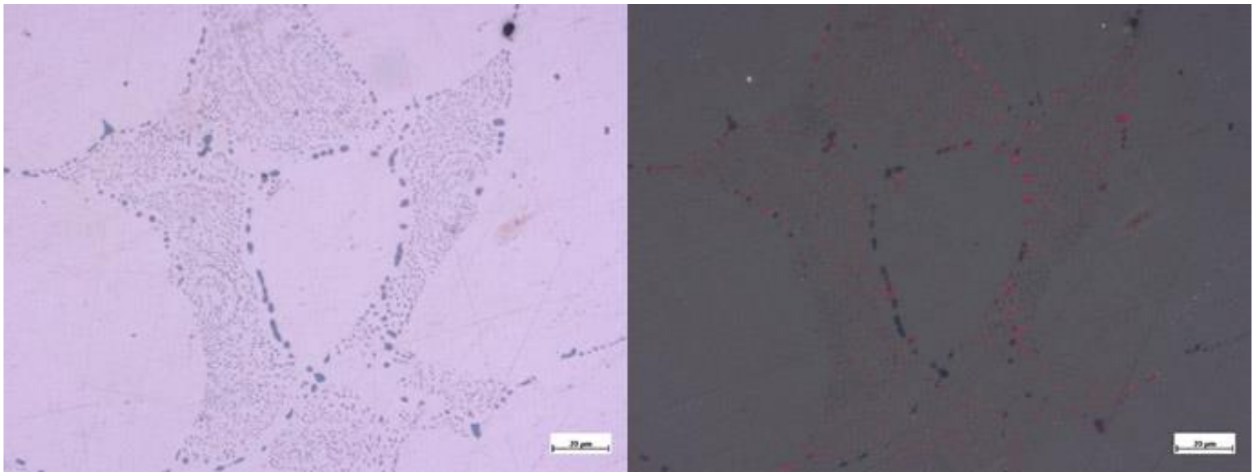


Figure 6-23: AT20765 – Detail showing rare occurrence of Cu-$Cu_2O$ eutectic. The image at left shows it under plain light where some of the larger inclusions in the ring at center can be seen to have red internal reflections. The image at right shows the eutectic under polarized light where the red represents $Cu_2O$, while the gray areas are $Cu_2S$. 500x mag.

also be observed. Finally, it is only in the case of refined copper where we see a single sample exhibits the Cu-$Cu_2O$ eutectic (Figure 6-23), indicating either extensive intentional refining or repeated episodes of melting (Bodsworth, 2018, pp. 172–176). Its rare occurrence would tend to indicate a low likelihood for recycling within this assemblage.

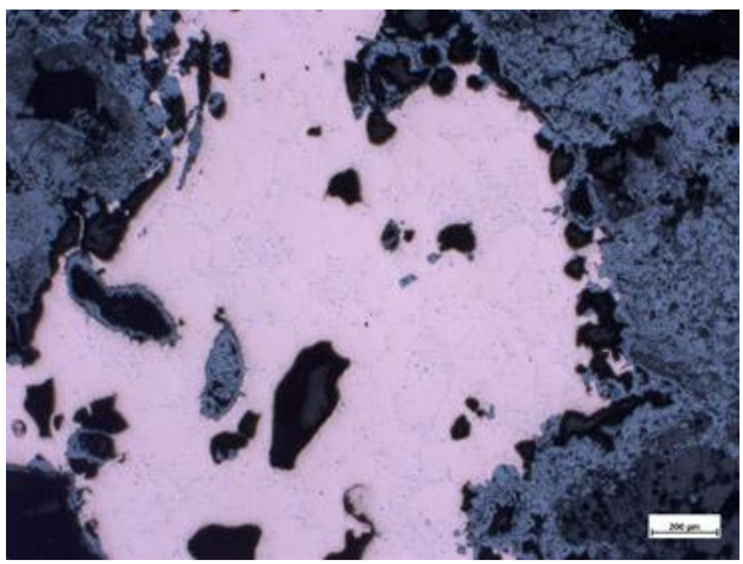


Figure 6-24: AT20717 – General view showing network of Cu-$Cu_2S$ eutectoid (light gray) at grain boundaries. Medium gray regions are post-depositional corrosion. Plain light. 50x mag.

Refined copper constitutes 15.15% (n=15) of the assemblage with eight samples being amorphous globules, while the remaining seven are composed of a chisel, an ingot, two points, two sheet fragments, and a piece of wire, showing a similar variability in object types to the high-tin bronzes. Microstructurally, all samples exhibit either a clear equiaxed or deformed (formerly equiaxed) microstructure, as is expected for unalloyed copper.

Furthermore, all samples contain copper sulfide inclusions, though the quantities vary. Among the amorphous fragments copper sulfide inclusions occur in the highest concentrations, often forming a eutectoid at grain boundaries (Figure 6-24). The continued minor presence of sulfur (0.4% in AT20717) and rare occurrence of copper oxides in these samples suggests a reasonably well-managed refining process for the production of blister copper (Bodsworth, 2018, p. 39).

Figure 6-25: AT20638 – General object photo. The left end possesses a square section that is progressively flatted to form a small blade at the right side. © 2020 Alalakh Archives

Of the objects in this category, the most surprising is what we have tentatively termed a "votive"[14] chisel – AT20638 (Figure 6-25) – that possesses a unique Ag-Cu alloy cladding. The core of the object itself is composed of relatively pure copper with minor (<0.29 wt.%) constituents of As, Fe, and S. Unfortunately, because the object has suffered such extensive corrosion, it is not possible to make substantive comments on the production process of the core. Nevertheless, the microstructure of the cladding left relict "ghost structures" that provide clues to its method of application. Figure 6-26 is a view of the cladding at a corner of the object where it is best preserved. Both images show the same spot in polarized and plain light. The region in the lower-right corner is composed almost entirely of cuprite (red and yellow in the polarized image, bluish and red in the plain light) and represents the original corner of the core. The cuprite

[14] The Hittites were quite fond of miniature objects for votive purposes (Akar, 2017, p. 6; Popko, 1978, p. 31; Yener, 2015a, p. 210)

regions at the upper left (outside the cladding) are a result of copper ion migration during corrosion. The belt in between these regions with a mottled silvery brown appearance in the polarized image, punctuated by areas of blue copper corrosion products represents the cladding. Meanwhile, in the plain light image, bright white inclusions are areas of silver that was redeposited during the corrosion process. If we consider that the brownish mottled areas are, based on their corroded morphology, the remnants of an Ag-Cu eutectic (28.1 wt.% Cu), while the blue areas would have had a likely composition around Cu-8 wt.% Ag. Making an extremely rough comparison with alloys of similar microsctructure (Northover and Northover, 2014, p. 178), the cladding may have had a composition around Ag-50 wt.% Cu. This, however, should only be considered a very rough estimated composition based on phase diagrams and visual comparison.

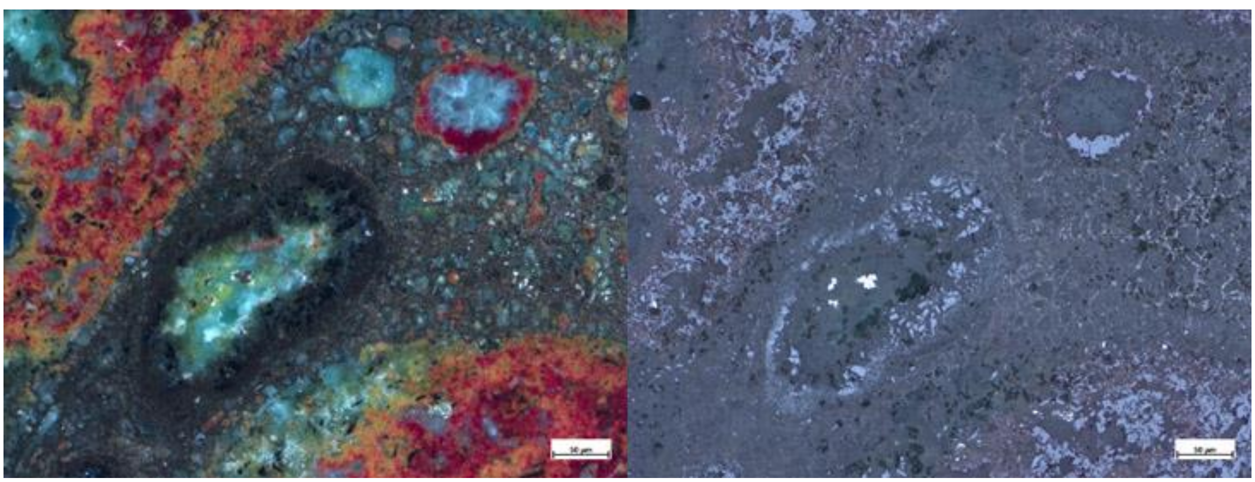


Figure 6-26: AT20638 – Polarized (left) and plain (right) light images of the corner or AT20638 where the cladding is best preserved. The “shimmering” gray and blue/green strip that occupies much of the polarized light image is the cladding. The blue/green islands constitute the Cu-rich β phase (30-100% Cu), while the mottled areas are a eutectic of ~28% Cu. The bright white spots in the right image are electrochemically redeposited silver that formed post-deposition. 200x mag.

As for the method of application of the cladding, there are two reasonable hypotheses – the first is that a sheet of foil was simply wrapped around the core, while the other is that the core was dipped into molten Ag-Cu alloy. Given that the microstructure of annealed Ag-Cu alloys tends to be relatively similar to the as-cast structure due to poor miscibility in the system, it is quite difficult to differentiate between the two processes (Subramanian and Perepezko, 1993, p. 62). The one clue in this respect is the apparently clean interface between the cladding and the original core where, had the object been coated by dipping, we would expect a less clearly defined boundary as the molten material would interact with the original core material in a similar fashion to dip tinning at high temperature (Meeks, 1993). This leads to the suggestion that the cladding may have been applied as a foil.

The ingot (AT24079) is a fairly interesting piece from two perspectives. First, in terms of it's composition, the fact that it contains approximately 0.4% Sn in association with its modest S, Fe, and As contents puts it into a similar class of material with AT8666 and AT8048 (see below). However, given the lower iron and sulfur contents of AT24079 and AT8048, it cannot be ruled out that these are in fact recycled material. From a microstructural perspective, AT24079 displays an extensive degree of cold working including strain lines, annealing twins, and substantial grain deformation. While the cold working of iron blooms into ingot forms is a well-attested practice, the tendency for copper ingots – which can generally simply be cast – to be cold worked is, to my knowledge, not especially common.

Of the two points manufactured from refined copper, AT23902 (see also, AT8499) constitutes a type of point for which there is still some debate as to its precise purpose, though the current thinking is that these were drill bits (Yener et al., 2019c, p. 157). AT24621, meanwhile, is an arrowhead with a blunted tip. In the case of AT23902, the microstructure is deformed to an extreme degree, pointing to extensive cold working. Annealing twins are abundant, however, the degree of crystal disregistry and obliteration of grain boundaries (**Error!**

**Reference source not found.**) suggests that the final working process resulted in between a 40-60% reduction (see; Rostoker and Dvorak 1990, 17). In either case, the degree of cold working involved here would have imparted a great increase in hardness, which could be taken as support for the hypothesis that these types of object were drill bits.[15] Further adding to this notion is the observation that these objects often show macroscopic indications of having fractured at the narrow point of their haft.

The microstructure of AT24621 is unremarkable. Grains are generally equiaxed with abundant annealing twins, some of which are deformed. Strain lines can also be identified. That said, in color-etched imagery, it is also possible to identify banding that, in combination with partially resorbed grain boundaries, can be taken as an indication of an incomplete final annealing process that induced recovery (relaxation of internal stresses) but not recrystallization (Humphreys and Hatherly, 2004, pp. 169–171). Given the difficulty of distinguishing these processes reliably, this is a tentative judgement.

[15] But see; Gwinnett and Gorelik (1999; 1987), who point out that soft metal used alongside an abrasive fits the wear pattern evidence for stone drilling more closely. As such, these may have been used for drilling something like wood or ivory.

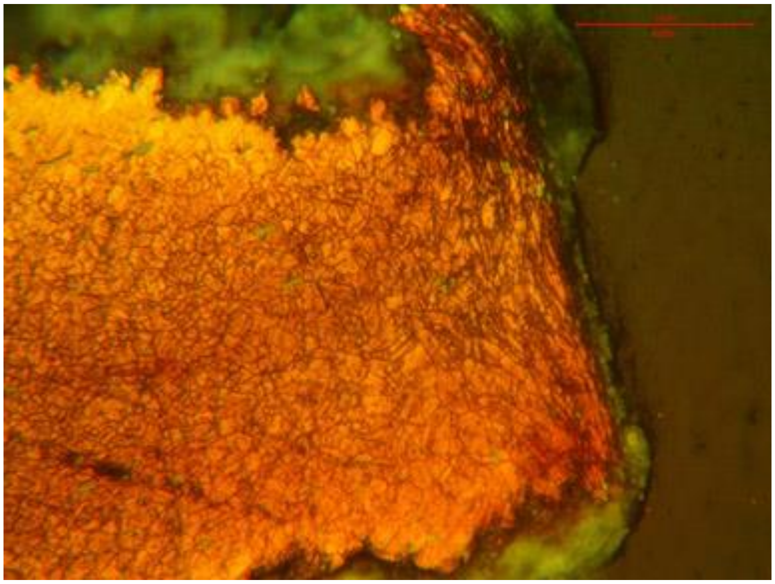


Figure 6-27: AT8048 – Detail showing equiaxed grain structure and deformed outer edge. $FeCl_3$ etch. 400x mag. Plain light.

As with the points, the two refined copper sheet fragments AT8048 and AT18608 represent fundamentally different types of object, despite being broadly classifiable as sheet metal. AT8048, as mentioned above, could be considered recycled material or could fall into the same category of high-Sn copper (but <1% Sn) as AT8666, albeit refined. As an object, it appears to be a decorative element composed of a strip of metal that has been rolled at one end. The general grain structure is equiaxed, with a very small grain size. Annealing twins are abundant, however, there are no strain lines except along one side of the sample where there is extensive deformation (Figure 6-27) of the structure that could be taken either as an attempt to dress a messy edge or, more speculatively, could be deformation resulting from an attempt to use this band as a piece of inlay.[16]

AT18608 represents something of a conundrum in terms of its identification. The microstructure exhibits significant deformation, as one might expect for sheet metal. However, the axis of deformation, rather than proceeding across the short (horizontal) axis of the object, proceeds across it's long (vertical) axis. Furthermore, along one side of the sheet, the grains

[16] In my own gunsmithing work, I frequently use strip brass as an inlay material that is lightly hammered into a narrow slit cut into wood or metal. The deformed edge is then usually dressed with a file and sandpaper. Depending on the degree of finishing work, a similar structure could result.

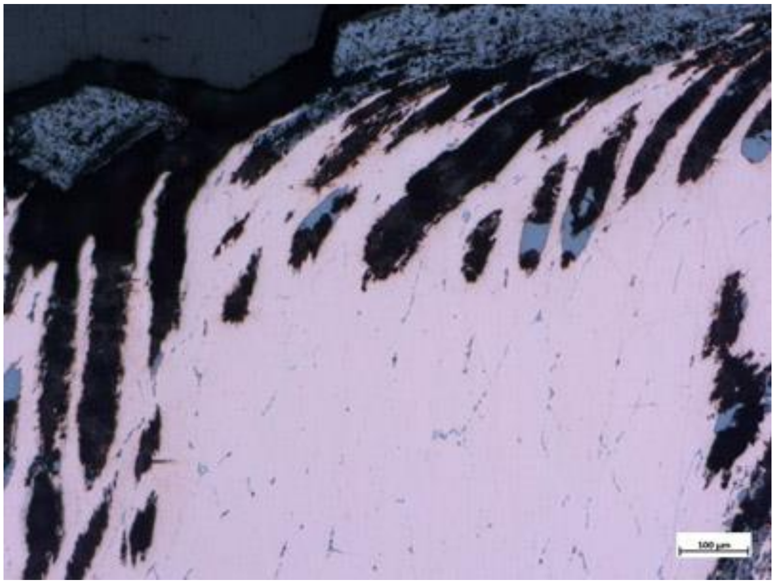


Figure 6-28: AT18608 – General view showing the smeared texture along a single side of the piece. Medium gray copper sulfide inclusions outline deformed equiaxed grains. When etched, strain lines are present, but not accompanied by annealing twins. 100x mag. Plain light.

exhibit a smeared texture (Figure 6-29), as though they had been dragged downward. Given the available evidence, it appears as though AT18608 is actually a fragment of metal that had been cut from the edge of a larger piece, probably with some sort of chisel since saws do not result in this type of unidirectional deformation. Interestingly, the observed features can be closely compared to the unidirectional machined microstructures (Shyha et al., 2018, fig. 1). An alternative hypothesis would be that this structure was created during sampling, which was my initial thought, however, even after grinding the sample beyond what should have been the tool affected area it was still present. Further that corrosion features follow this structure without signs of fracturing is further evidence that this is an original structure.

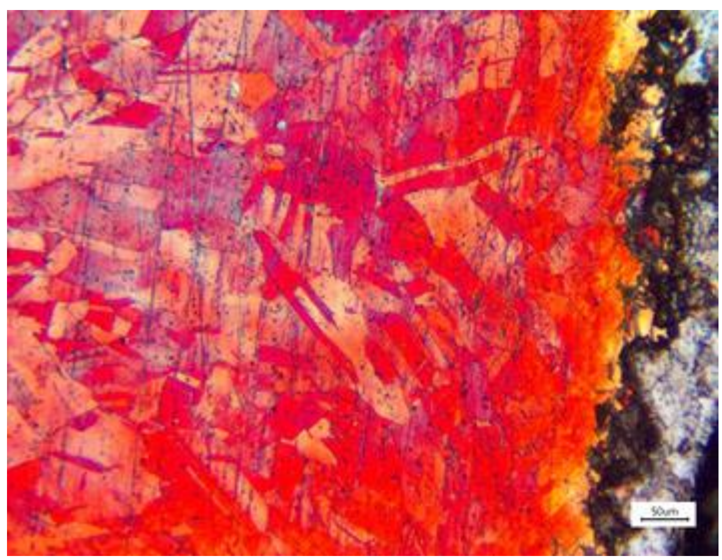


Figure 6-29: AT8906 – view showing the seemingly random pattern of grain distortion in this sample. The one notable trend is the tendency for grains toward the surface (right) to appear stretched while those toward the center seem to have been more compacted. Klemm's I etch. 100x mag. Plain light.

The final object in this category, AT8906 (Figure 6-29), is a short fragment of wire (or a very narrow shaft). The microstructure is heavily deformed, showing abundant deformed annealing twins as well as strain lines. Worth noting is that while most objects examined so far have exhibited some sort of directionality in their deformation, that seen here appears to be largely random. This can be explained by two possibilities, the first being that the apparently random deformation patterns are a result of the stacking of dislocations as the object was rotated and worked down to a small diameter, while the other is that the object was formed by being drawn though a drawplate. I am inclined toward the second possibility in this case because of the stretched morphology of the outer grains, while the inner grains have retained more semblance of their equiaxed forms, this pattern deriving from the fact that the outer surface will tend to undergo smearing and stretching while the inner grains become compressed (Wu et al., 2019). Nevertheless, the evidence available does not allow a definitive judgement to be made.

### *6.2.5 Cupronickel and Cu-Ag-Ni*

Though the two alloys discussed here are completely distinct from one another, their exceptionally high Ni content sets them apart from the rest of the assemblage at Alalakh. Cupronickel is a broad category that has been variously used to describe alloys of copper and nickel with <1 wt.% Zn, where Ni

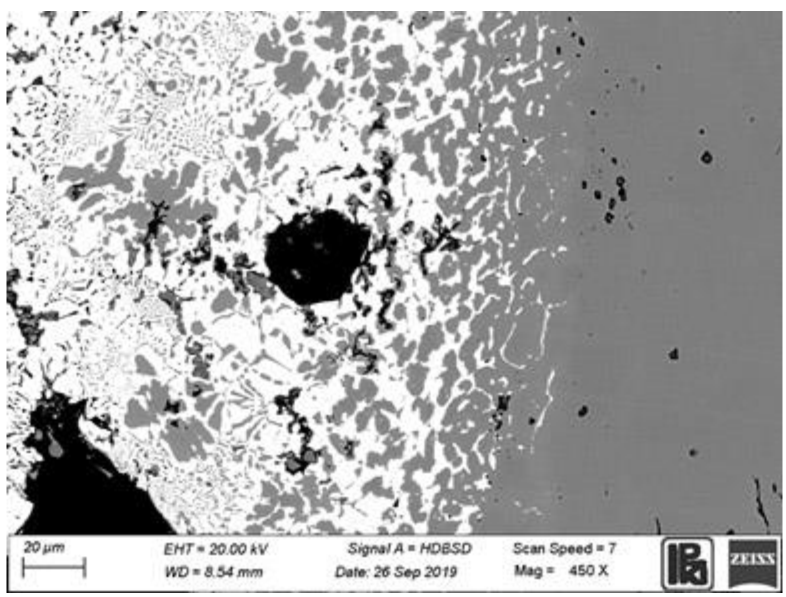


Figure 6-30: AT21204 – BSE image of the interface between the upper Cu-Ni layer (right) and the lower Cu-Ag layer (left).

constitutes the second most abundant element, an alloy with a composition of Cu-20 wt.% Ni, or alloys with <50 wt.% Ni. In the case of a single fragment of wire from Alalakh (AT8915), the Ni content is 13 wt.%, placing the object firmly within the category of cupronickel. Though not an especially abundant alloy in ancient assemblages, it is most certainly not unheard of and corresponds well with other examples (Lehner, 2015, pp. 159–167; Lehner and Schachner, 2017, pp. 412–413), often being used as a decorative element, most likely due to its pale silvery color. The wire fragment is quite thin, possessing an equiaxed grain structure with abundant annealing twins.

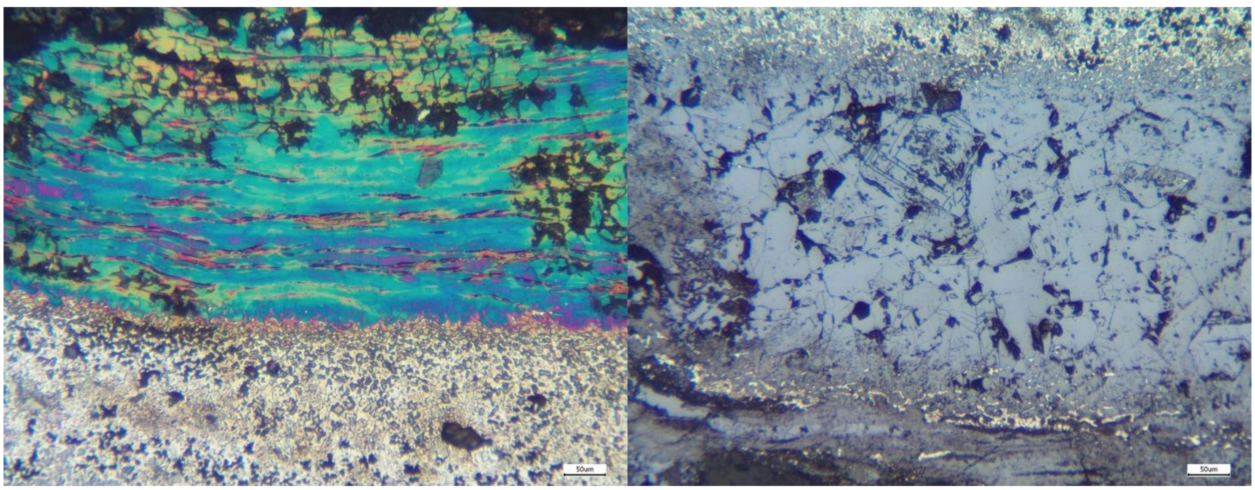


Figure 6-31: AT21204 – Plain light images at 100x mag. Left: Etched with Klemm's I reagent. The upper blue/yellow portion is the Cu-Ni phase. Bands running across it are composed of constellations of deformed copper sulfide inclusions. The extent to which this phase penetrates into the white/gray Cu-Ag phase can be seen by the islands of multi-colored material descending downward. Right: Corroded layer at the "bottom" of the sample. Prior to etching, no structure was visible, however Klemm's I revealed clear grain structure with annealing twins. Beneath this is another fine layer of Cu-Ag that wraps around the entire object.

AT21204 is composed of a Cu-Ag-Ni alloy, for which I am not currently aware of any parallels. This material, due to the complete immiscibility of the Cu-Ni phase (Cu-13% Ni) with the Cu-Ag phase (Ag-7% Cu), displays an interesting segregation pattern with the lower melting (~800°C) silver-bearing phase being completely excluded from the higher-melting (~1,200°C) nickel-bearing phase (Figure 6-30) (Chang et al., 1977, p. 644). More curious, however, is limitation of the Cu-Ag phase to the center of the object with a fine layer extending all the way around, apparently encasing two halves composed of Cu-Ni. Based on the etched microstructure of the Cu-Ni phase, showing annealing twins and deformed inclusions (Figure 6-32 and Figure 6-31), this object has been worked, meaning that it is not simply a flow of material that cooled in a strange manner. Finally, given the large variation in melting temperature, the interpenetration of the two phases seems likely to be a remnant of casting, rather than an artifact of some kind of dip coating process, while the coating of Cu-Ag over the whole object suggests it is not due to soldering or brazing. While some combination of the above might result in the observed structure, none of these can be reasonably clarified here, save to say that this is indeed an intentional object.

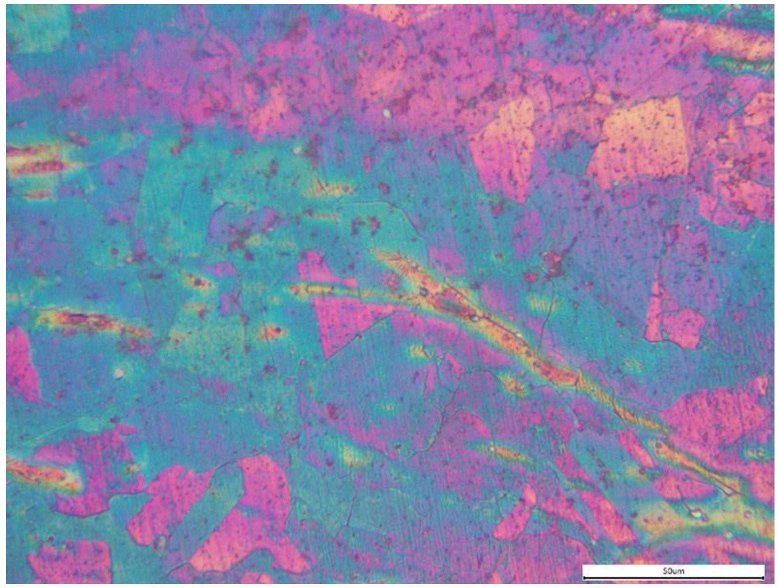


Figure 6-32: AT21204 – Detail of etched Cu-Ni phase, showing networks of small inclusions (silver) along bands. Annealing twins are clearly visible. 400x mag. Plain light.

### *6.2.6 Heterogeneous Smelting Product (HSP)*

HSP is a general term that encompasses samples that to not fall cleanly into categories of metal or slag, often containing appreciable quantities of both as well as matte (copper and iron sulfides, typically chalcocitic in composition). Because of this heterogeneity, it seemed most reasonable to treat this handful of fragments as their own category, though most could reasonably be assigned to the Raw Copper group or the Smelting Slag group. This provides us with the primary criterion for defining a sample as HSP – that it contain smelting slag and raw copper. Beyond this I have also made allowance for samples containing appreciable quantities of matte alongside smelting slag. Because any subsequent treatment of the metal after the smelting process – whether that is refining, melting for casting, or even simply cold working – would separate the slag from the metal via melting or breakage, we can state with a high degree of confidence that this is material that was removed from the smelting furnace and then entered into the archaeological record.[17] As for the matte-slag agglomerations, the status of both of these materials as smelting byproducts is beyond dispute, making the designation more or less self evident. As a category, HSP makes up 5.05% (n=5) of the overall assemblage. All fragments are amorphous.

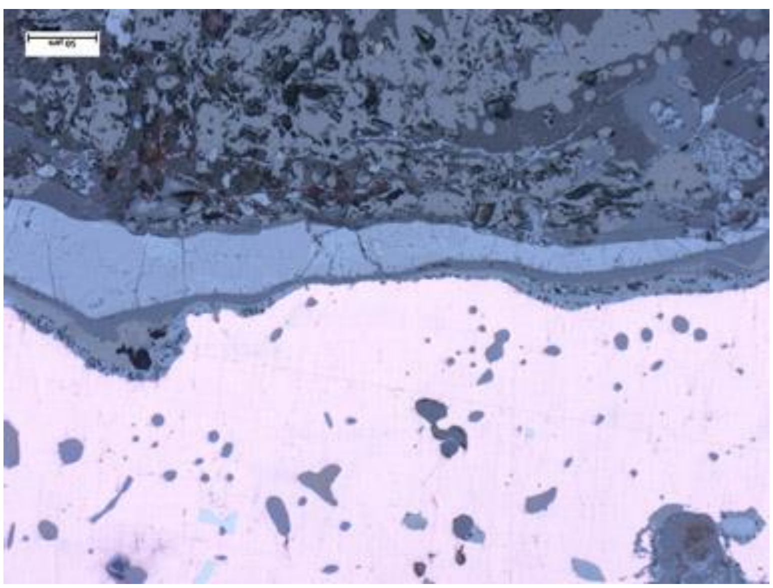


Figure 6-33: AT19330 – Interface between slag (mixed region at top) and metal with a thin band of matte (blue-grey, chalcocitic composition with magnetite eutectic) between the two. Within the copper metal, inclusions of metallic iron (light gray) and copper sulfide (dark gray) are visible. 200x mag. Plain light.

Following the above discussion, we can divide HSP into two general groups – one composed of slag and metal (n=5) (Figure 6-33) (cf. Renzi et al., 2018, fig. 6.10), and the other being slag and matte (n=2) (Figure 6-34). The smelting slags can be further subdivided in fayalitic and forsteritic varieties (Bourgarit, 2019, p. 213). The most predominant manifestation of HSP

[17] There may have been some movement in between these steps, but no further processing.

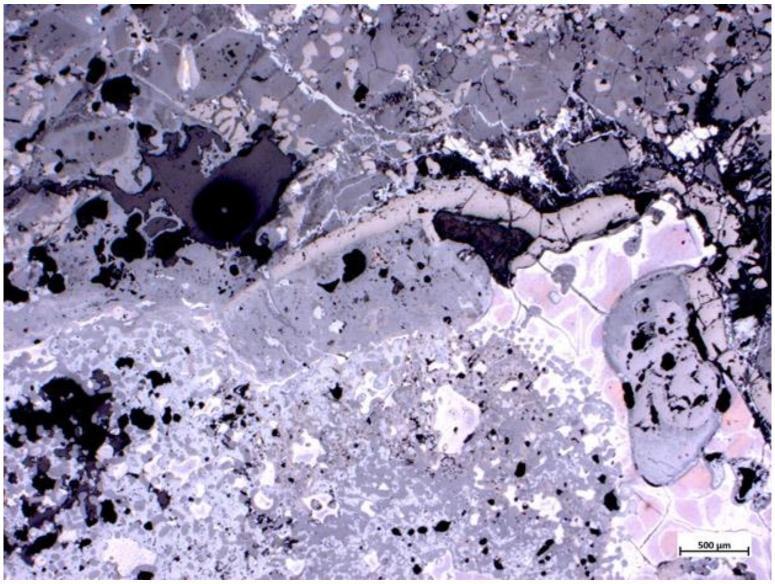


Figure 6-34: AT4327 – Slag-matte interface. The upper portion is an Mg-rich slag with large euhedral grains of forsteritic composition with a lighter rim closer to fayalite in composition. Light gray inclusions are generally wüstite. The lower portion is matte of primarily chalcocitic composition (bluish white) with some bornite (purple) and remaining chalcopyrite (yellow). Gray and olive-brownish blobs are iron sulfides. 50x mag. Plain light.

is large globules of raw copper with adhering fayalitic slag, often containing large quantitites of copper sulfides and free iron oxides. Copper sulfides typically exhibit compositions in the range of chalcopyrite, bornite, and cubanite (Bachmann, 1982a, p. 16). Often it is possible to identify a copper sulfide parting layer with a chalcocitic composition between the metal and slag, or sometimes surrounding globules of metal (Figure 6-33). As a general process indicator, the chalcocite parting layer also tends to host a magnetite eutectic phase, demonstrating cooling from a completely liquid state, and identifying this material solely as the byproduct of pyrometallurgical processes (Hauptmann, 2011, p. 198; Personal Communication, Th. Rehren 2019).

The two slag-matte agglomerations (cf. Bachmann, 1982b, p. 16)  in the assemblage show a similar pattern of layered formations in line with the slag-matte-metal partioning laid out by Thronton et al. (2009, p. 309). In those instances where we see a more or less direct slag-metal interface, we can suggest that the matte had undergone almost complete conversion to metallic copper (Bodsworth, 2018, p. 39), while in cases where we only see slag and matte, we may hypothesize that this material is representative of an earlier point in the smelting process.

The larger quantities of iron sulfides in this latter class of material would tend to support this assertion, since they oxidize relatively easily and become part of the slag layer or reduce to metallic iron as smelting progresses.

This may be illustrated in the fact that slag-matte agglomerations tend to display a mineral assemblage richer in Mg and Al, reflecting the tendency of both elements to form stable oxides before Fe (Figure 6-35). In these slags, this is typically in the form of olivines approaching a forsteritic composition and spinels approaching a hercynitic composition. As the smelting process proceeds and iron sulfides oxidize, the slag melt would become increasingly enriched in Fe, shifting closer to the composition of fayalite as seen in the metal-rich HSP samples. One manifestation of this process of progressive enrichment is the zoning visible in the large

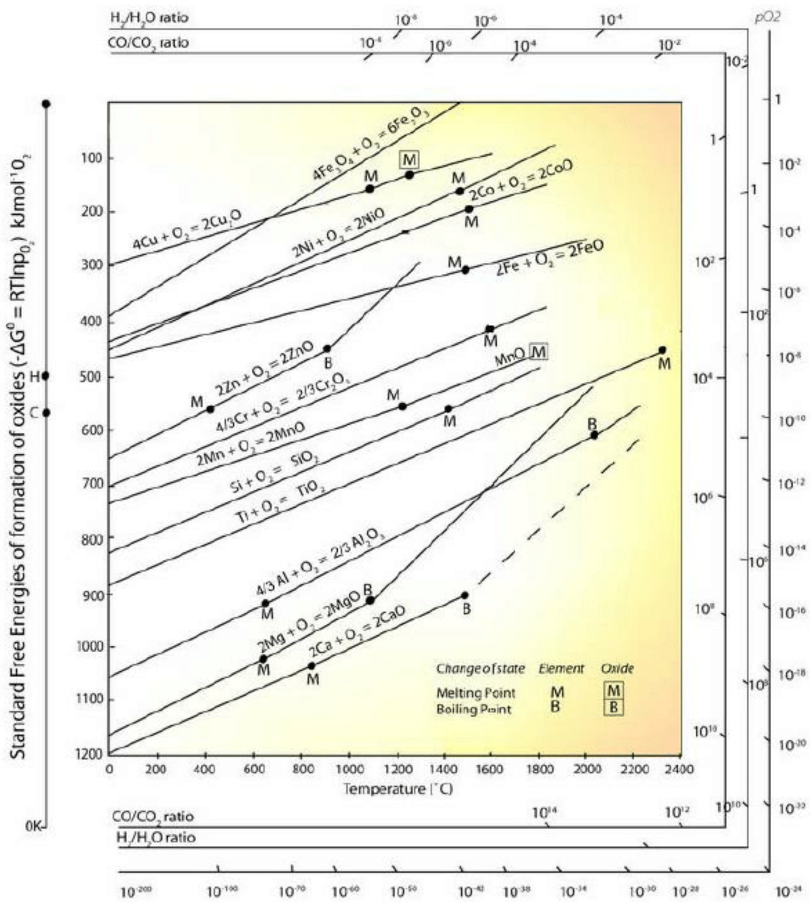



Figure 6-35: Ellingham diagram displaying enthalpy of formation for metal oxides relevant to this study. For the processes represented in this discussion, a temperature around 1200-1300°C should be assumed. As a general explanation, the lower a given oxide appears on the diagram, the more easily it will form, reflecting an increased tendency for a specific element to enter slag. There are a variety of other considerations represented here such as atmospheric composition, but given that such diagrams represent ideal conditions, their specific relevance to ancient processes is limited. Image from University of Cambridge DoITPoMS.

crystals of Figure 6-36. As the formation of the core of these crystals depleted the melt of Mg, its composition became enriched in iron, giving newly crystallizing material a progressively more fayalitic composition. It is also possible, however, that these result from a different ore than the fayalitic slags, given that AT21470 (below) contains relatively little copper sulfide.

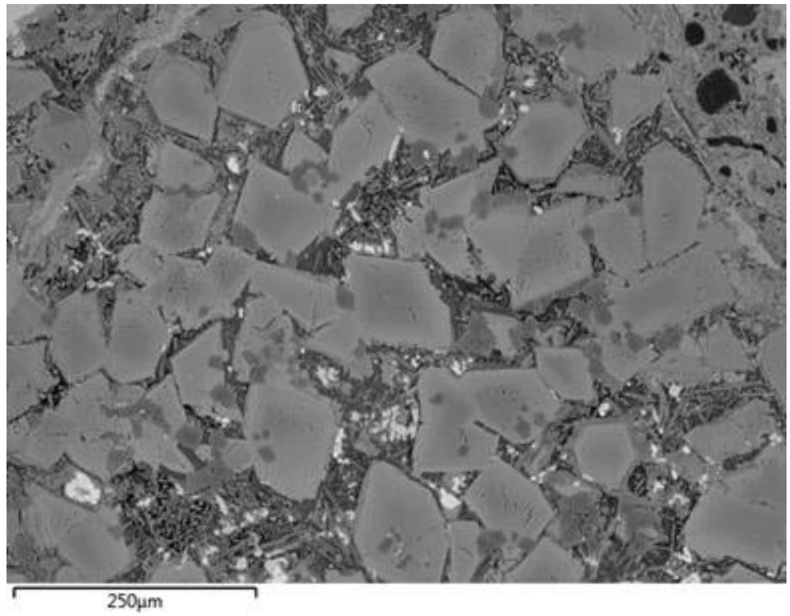



Figure 6-36: AT18636 – BSE image of slag portion of the sample, highlighting the highly geometric form of the forsterite-fayalite grains (light gray, zoned) and hercynite (medium gray) crystals.

### *6.2.7 Smelting Slag*

As a general material, smelting slags are identified on the basis of the mineral assemblages present and the types of redox conditions that these represent as clues to the types of processes taking place (Bachmann, 1982a, pp. 13–18). In the case of smelting metals, where the maintenance of a reducing atmosphere is necessary to convert sulfides and oxides of metals to their elemental states, we tend to look for mineral assemblages that incorporate elements with lower oxidation states, with a particular focus on the state of iron since its presence as $Fe^{2+}$ or $Fe^{3+}$ is a relatively sensitive indicator of the prevailing redox conditions in a given environment (Figure 6-35). When examining a slag, the presence of minerals in the olivine series – and particularly the Fe-rich end member of that series, fayalite – is indicative of a more reducing atmosphere, since the crystal lattice of fayalite is usually only able to accommodate the $Fe^{2+}$ ion.

Similarly, when looking at the free iron oxides of wüstite ($Fe^{2+}O$) and magnetite $Fe^{2+}(Fe^{3+})_2O_4$, we can see that the former, since it only forms with the $Fe^{2+}$ ion, requires a more reducing atmosphere than the latter. However, because magnetite also requires a ferrous (2+) ion to form, it still needs a more reducing atmosphere than hematite, which requires only the ferric (3+) ion. In this respect, we can see that these three forms of iron oxide essentially represent varying redox conditions. Having laid out this rather idealized set of rules, however, it is important to keep in mind that the atmospheric conditions in ancient (and modern, for that matter) furnaces are highly variable, and so a contextual approach must be taken to the evaluation of any given sample. That is to say that the presence or absence of a particular mineral should not be taken as determinative, but rather, considered part of an aggregate whole.

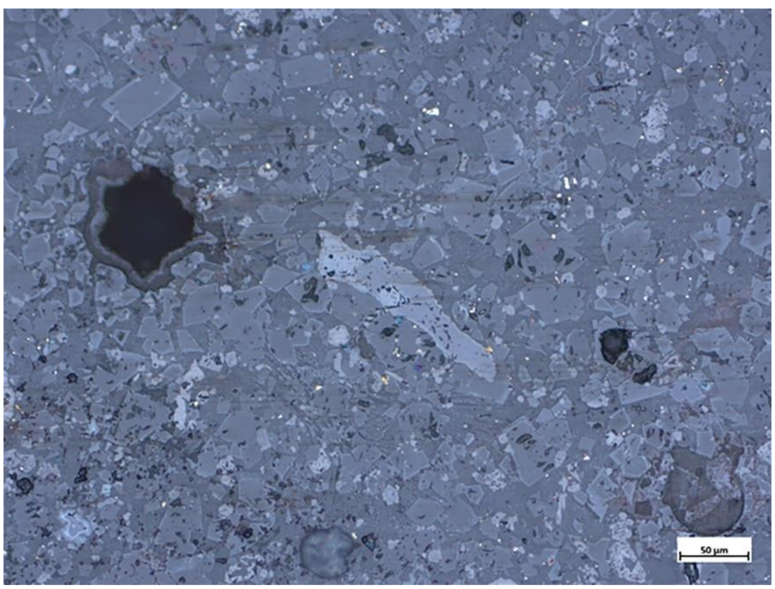


Figure 6-37: AT21470 – General view showing abundant Mg-rich olivines (medium gray) in a glassy matrix. Light gray blebs are wüstite while pale yellow and blue globules are chalcopyrite and covellite, respectively, the latter generally being a corrosion product. The irregular light gray grain at center is chromite, representing original geological material from the smelting charge. 200x mag. Plain light.

As discussed above, the HSP category should be considered an extension of Smelting Slags, and as such, the slags seen there will be discussed here. With that in mind, the number of slag samples that can be solely attributed to this category is one – AT21470 (Figure 6-37). Two other samples, AT4327 and AT8019 have been assigned here as well, although the former could also reasonably be put into the HSP cateogry, while the latter warrants some discussion, appearing more as an agglomeration of minerals on their way to becoming slag.

A first point to note about the smelting slag assemblage from Tell Atchana is that all of the fragments are highly amorphous – not displaying any sort of flow patterns or other features that are typically used to classify slags macroscopically (i.e. Catapotis and Bassiakos, 2007, p. 78; Hauptmann, 2011; Kraus et al., 2015, p. 303). All fragments are relatively small, rarely measuring much more than 2cm across. The one exception to this is AT4327, which is by far the largest and heaviest fragment at around 4cm in diameter with a weight of 125g. When compared to slags from more well known LBA smelting sites such as *Politiko*-Phorades or Timna, both the overall quantities and individual fragment sizes of the Atchana slags are miniscule at best (Hauptmann, 2007; Knapp et al., 2001; Knapp and Kassianidou, 2008; Yagel et al., 2016).[18] Given that, aside from AT21470, none of the fragments appear to have been fractured from larger cakes of slag, I hypothesize that these are globules of material that did not descend completely to the bottom of the furnace to agglomerate with the pool of molten material accumulated there, becoming trapped somewhere in the fuel bed at the end of the smelting operation.

In terms of general characteristics, two types of smelting slag are present at Alalakh, with one displaying a mineral assemblage more dominated by iron, while the other displays more magnesium and aluminum. In terms of its mineral assemblage, the former typically exhibits large

[18] *Cf.* Chapter 3 for commentary on building practices at Atchana and the tendency for houses to be cleaned out frequently. As it stands, this is the best explanation I can currently provide for the vanishingly small amounts of smelting debris.

quantities of fayalite and wüstite/magnetite within a glassy matrix, typically accompanied by modest quantities of copper sulfides (Figure 6-38). Inclusions of metallic copper are uncommon, and when they do occur, they are typically quite small and often contain around 3% Fe, approaching the saturation point for iron in copper, after which it precipitates as globules of metallic iron.

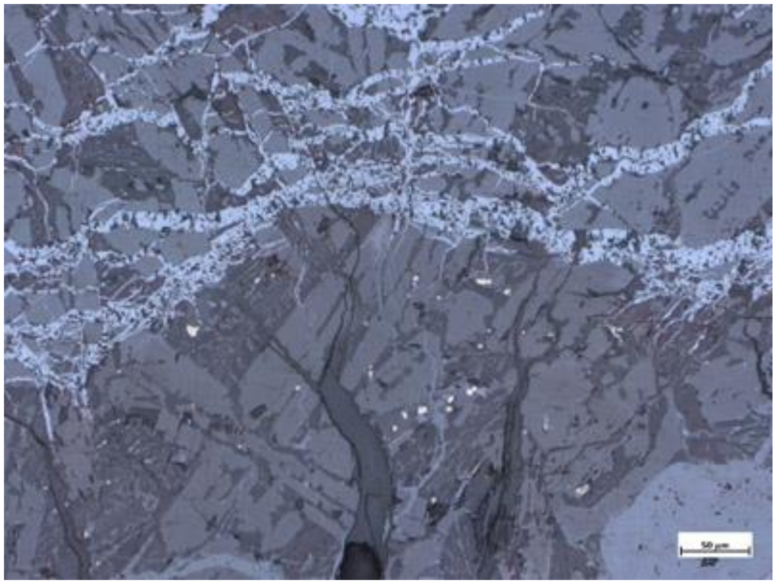


Figure 6-38: AT23799 – fractured grains of skeletal fayalite (medium gray) in a glassy (dark gray) matrix with globules of chalcopyrite (yellow). Blue veins in the upper field are cuprite formed post-deposition from corrosion of associated metallic copper. 200x mag. Plain light.

Looking at the Mg and Al-rich slags, the mineral assemblage is comprised of small, idiomorphic grains of hercynite which form the first set of minerals to have cooled from the melt (Figure 6-36). These are typically incorporated inside zoned grains of olivine with a forsteritic composition at the center that moves toward a fayalitic composition approaching the outer rim (Figure 6-37). There is often a mixed assemblage of iron oxides including both magnetite and wüstite, with the former playing host to whatever inclusions of metallic copper may be present. The copper sulfide content tends to be significantly higher than in the fayalitic slags, appearing as large globules or rims around the outside of corroded copper prills, and exhibiting a core of chalcopyrite with a bornite exsolution and an outer layer approaching a chalcocitic composition (Figure 6-39). Two slags of this type are in association with large agglomerations of matte

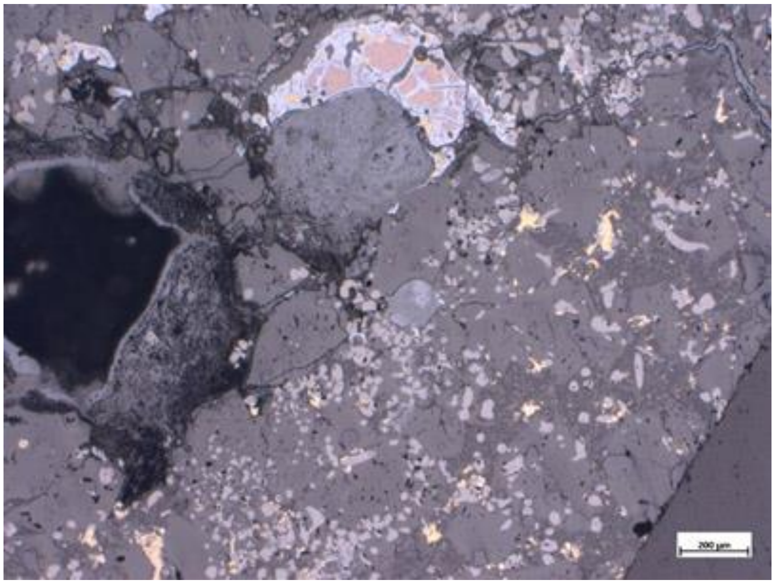


Figure 6-39: AT4327 – at the upper portion of the image, a halo of copper sulfides (blue, purple, yellow) engulfs one edge of a now fully corroded copper prill. 50x mag. Plain light.

(AT4327 and AT18636), composed almost entirely of copper and iron sulfides, and show close similarities to material from LBA Kalavasos (Van Brempt and Kassianidou, 2016).

As mentioned above, it is possible that, rather than reflecting two separate smelting procedures or ore compositions, these different varieties of slag could also represent different points in the smelting process. In such a scenario, the fayalitic slags and their close association with raw copper, would originate from the end-stage of the smelting process, where the vast majority of the copper sulfide has been converted to copper metal, while the iron in the system has either been incorporated into the slag as iron oxides, or into the copper as metallic iron. The Mg-Al rich slags, being associated with iron and copper-rich matte, would stem from an earlier stage in the process, before reduction of the copper sulfides has completed and before the iron present has reduced or been oxidized. As a result, the more easily oxidized magnesium and aluminum would be relatively enriched in this early slag, becoming diluted as the iron content increased.

Working against this scenario are subtle indications from AT21470, AT19330, and AT8019, which suggest that there may be at least two (if not three – see; Speiss) smelting regimes in practice at Tell Atchana. In the case of AT21470, we are presented with a slag that possesses the mineral assemblage associated with the Mg-Al rich slags. However, the quantities

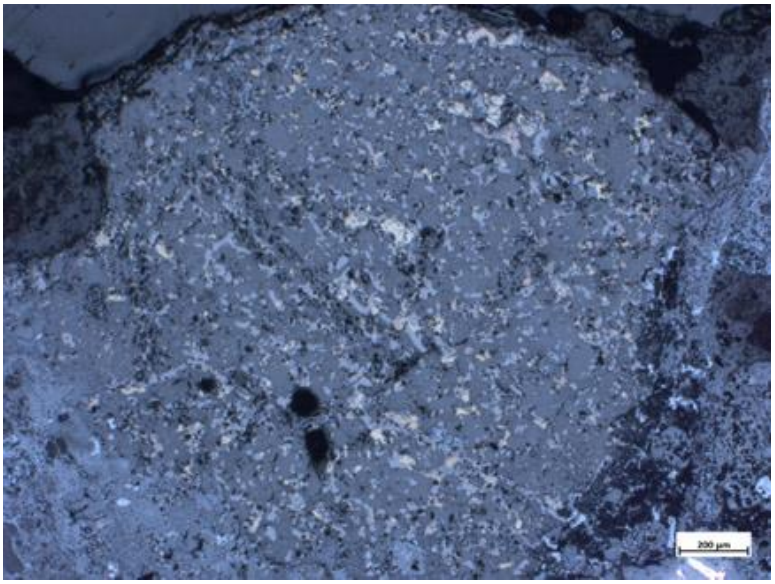


Figure 6-40: AT19330 – Overview of adhering slag globule showing abundant copper culphides, primarily cubanite (brownish yellow) and chalcopyrite (yellow). 50x mag. Plain light.

of copper sulfide present are significantly lower than in the other examples and the completeness of slag formation is more advanced based on its greater homogeneity. As such, while we can still view AT4327 and AT18636 as "early stage" slags based on the abundant sulfide assemblage, the potential endpoint represented by AT21470 argues against the dilution hypothesis stated above. Furthermore, AT19330, from the HSP category, displays an unusually large quantitity of copper sulfides entrapped in its slag matrix (Figure 6-40), with a particular tendency towards chalcopyrite and cubanite, which are likely representative of the original ore. As such, the fayalitic slags do sometimes contain substantial quantities of iron rich matte. This does not necessarily suggest a deliberate choice, but rather, could also be attibuted simply to different varieties of gangue material mixed into the ore charge from different batches of material.

| AT8019 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mixed Spinel | O | Mg | Al | Si | Ti | Cr | Fe | Co | Cu | Zn | Sn |
| | 54.5 | 7.11 | 3.37 | 5.27 | 0.59 | 1.28 | 25.4 | 0.61 | 1.1 | 0.3 | 0.5 |
| | 53.2 | 5 | 3.41 | 1.82 | 0.86 | 0.27 | 33.1 | 0.68 | 0.8 | 0.3 | 0.5 |
| | 52.7 | 5.77 | 3.46 | 2.61 | 0.75 | 0.3 | 31.8 | 0.74 | 0.9 | 0.4 | 0.5 |
| Chromite | O | Mg | Al | Ca | V | Cr | Fe | Co | Cu | Zn | |
| | 52.9 | 8.24 | 12.5 | 0.1 | 0.15 | 17.4 | 7.38 | 0.53 | 0.5 | 0.3 | |
| | 52.4 | 8.53 | 12.5 | nd | 0.15 | 17.9 | 7.3 | 0.46 | 0.5 | 0.2 | |
| Augite | O | Na | Mg | Al | Si | K | Ca | Ti | Fe | Cu | |
| | 56.8 | nd | 9.89 | 0.87 | 21.1 | nd | 9.82 | nd | 1.5 | nd | |
| | 56.3 | nd | 9.6 | 0.9 | 21.4 | nd | 8.9 | 0.1 | 2.7 | nd | |
| | 57.6 | nd | 8.68 | 1.03 | 20.7 | nd | 8.87 | 0.15 | 3 | nd | |
| Anorthite | 58.9 | 0.46 | nd | 15.9 | 16.9 | nd | 7.79 | nd | 0.1 | nd | |
| | 58 | 3.34 | nd | 13 | 20.5 | 0.06 | 4.79 | nd | 0.2 | 0.2 | |
| | 59.1 | 5.12 | nd | 8.54 | 24.7 | 1.73 | 0.4 | nd | 0.1 | 0.2 | |
| Enstatite | 54.1 | nd | 23.6 | 0.29 | 18.5 | nd | 0.06 | nd | 3.4 | 0.1 | |
| AT4327 | | | | | | | | | | | |
| Forsterite | O | Mg | Al | Si | Ca | Fe | | | | | |
| | 54.3 | 9.33 | 0.11 | 15.1 | 0.88 | 20.3 | | | | | |
| | 54.2 | 10.6 | 0.15 | 15.2 | 0.37 | 19.6 | | | | | |
| | 54.1 | 10.6 | 0.17 | 15.1 | 0.41 | 19.7 | | | | | |
| Hercynite | O | Mg | Al | Ti | Cr | Fe | | | | | |
| | 53.1 | 3.64 | 27.9 | nd | 0.12 | 15.2 | | | | | |
| | 53 | 2.31 | 28.1 | 0.08 | nd | 16.5 | | | | | |
| | 53.4 | 1.82 | 28 | 0.1 | nd | 16.7 | | | | | |
| AT18636 | | | | | | | | | | | |
| Forsterite | O | Mg | Si | Ca | Fe | | | | | | |
| | 54.4 | 10.1 | 15.1 | 0.53 | 19.8 | | | | | | |
| | 54.6 | 10.4 | 14.9 | 0.52 | 19.6 | | | | | | |
| | 54.8 | 8.86 | 14.9 | 0.68 | 20.8 | | | | | | |
| Hercynite | O | Mg | Al | Si | Ti | V | Cr | Fe | | | |
| | 54.4 | 3.23 | 27.2 | 0.15 | 0.16 | 0.17 | 0.16 | 14.6 | | | |
| | 52.9 | 4.22 | 27.8 | nd | 0.12 | 0.16 | 0.63 | 14.2 | | | |
| | 54.2 | 3.14 | 26.9 | 0.18 | 0.27 | 0.16 | 0.17 | 15 | | | |
| AT16577 | | | | | | | | | | | |
| Fayalite | O | Mg | Al | Si | S | Ca | Fe | Cu | | | |
| | 57.9 | 2.53 | 0.75 | 12.7 | 1.34 | 0.61 | 22.4 | 1.8 | | | |
| AT19330 | | | | | | | | | | | |
| Fayalite | O | Mg | Si | Ca | Fe | | | | | | |
| | 57.1 | 4.12 | 14.1 | 0.96 | 23.8 | | | | | | |
| | 57 | 3.63 | 14.1 | 1.44 | 23.9 | | | | | | |
| | 57.1 | 3.34 | 14.2 | 1.27 | 24.1 | | | | | | |
| AT21470 | | | | | | | | | | | |
| Olivine | O | Mg | Al | Si | Ca | Fe | | | | | |
| | 57.4 | 5.7 | 0.6 | 14.6 | 0.68 | 21 | | | | | |
| | 57.1 | 15.5 | nd | 14.2 | 0.22 | 13 | | | | | |
| | 54.9 | 20.1 | nd | 15.3 | 0.22 | 9.46 | | | | | |
| Chromite | O | Mg | Al | Si | Cr | Fe | Cu | | | | |
| | 56.9 | 10.8 | 6.55 | 0.17 | 20.6 | 4.15 | 0.82 | | | | |

Table 6-4: SEM-EDS point analyses of major phases in some of the smelting slags, as well as AT8019. The three point measurements are left unaveraged here to show variation between each of the measurements. Results are in at%

Finally, there is AT8019, which I suggest may be an agglomeration of fused minerals that are in the process of becoming slag, but have not yet fully melted. Upon initial optical examination, the dominant assemblage of spinels (Figure 6-41) is particularly striking and leads to a preliminary judgement that the sample is most likely a crucible slag (but see, Hauptmann, 2011, fig. 19.10). This would seem to be further supported by the presence of large quantities of metallic copper, and the high bulk content of copper 11.21 wt.% CuO. However, at a macroscopic level, and upon closer examination, it is possible to identify large regions of material that contstitute individual, partially fused grains (Figure 6-42). Based on SEM-EDS analysis (Table 6-4), many of these grains have compositions approaching anorthite or non-stoichiometric feldspars, as well as enstatite and pigeonite. While some of these, such as enstatite, can occur in slags, their morphology as large individual crystals (some almost 1mm across) generally identifies them as geological material. To this, we can then add the presence of chromite – as seen in smelting slag AT21470 (Figure 6-37), as well as at other sites in Anatolia – as a further marker of original geological material (Figure 6-43)[19] (Hauptmann et al., 2002b, p. 60; Yalçın et al., 1993). Aside from the presence of geological materials two other points are relevant. Although magnetite does form a substantial proportion of the mineral assemblage, there are frequent pockets where fayalite has begun to form from the magnetite-rich matrix, indicating a shift toward a more reducing atmosphere. Finally, the composition of some spinels with elevated contents of Cr would tend to suggest an

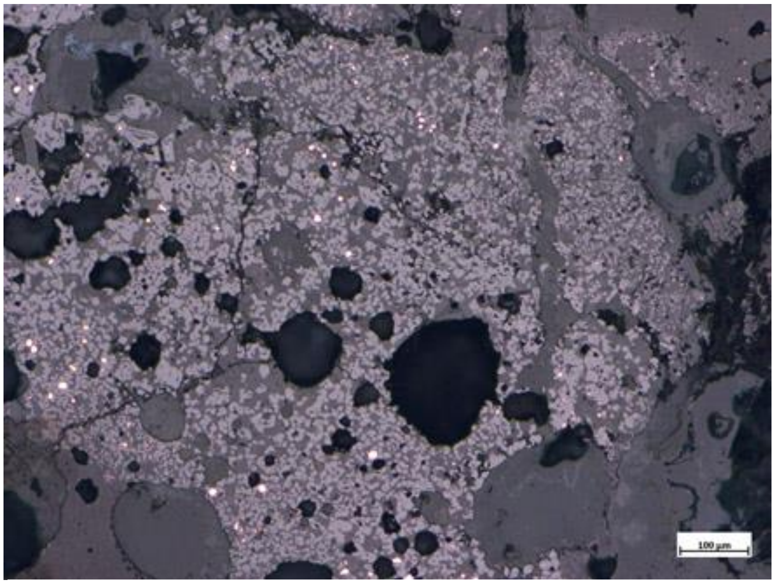



Figure 6-41: AT8019 – General overview showing large field of free iron oxides (light gray), mostly composed of magnetite. Bright orange-white globules are metallic copper, while whisps of blue are covellite. 100x mag. Plain light.

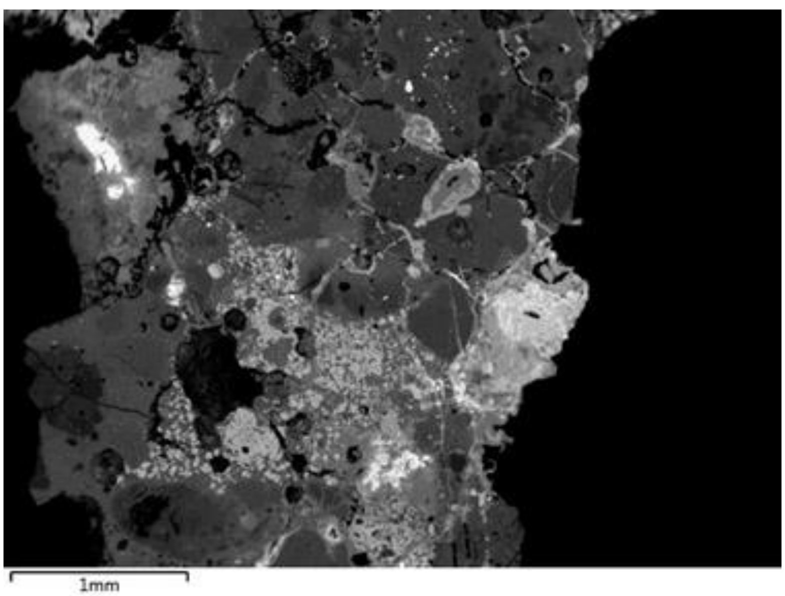



Figure 6-42: AT8019 – BSE image showing partially fused material at the center of the sample. Note that many grains are close to 0.5-1mm across, while the largest olivines in AT21470 are 0.05mm. The large size suggests that these are unreacted geological material.

[19] Due to its high melting point in the 2200°C range (depending on precise composition), grains of chromite do not generally melt under ancient smelting conditions. As such, their presence, and often highly irregular grain shape is indicative of original geological material being present in the furnace.

association with smelting since its tendency to readily oxidize (Figure 6-35) even under reducing conditions means that it would most likely be removed at the smelting stage

### 6.2.8 *Crucible Slag*

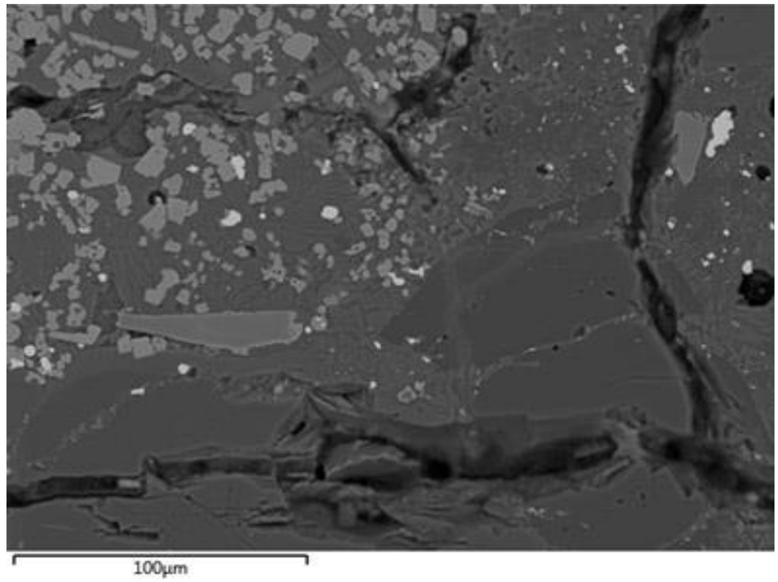



Figure 6-43: AT8019 – BSE image showing two grains of chromite in this frame as irregular medium gray crystals with a light-gray rim, one at the bottom of the magnetite field (light gray crystals) and the other at the upper-right of the image, adjacent to a bright globule of metallic copper..

While smelting slags are generally identified based on the presence of minerals formed from iron and other elements at low oxidation states, slags containing appreciable quantities of minerals with elements at high oxidation states are generally considered crucible or tuyere slags (Bachmann, 1982a, pp. 14–16; Bourgarit, 2019, p. 214; Hauptmann, 2011, fig. 19.10, 2007, p. 168). The reason for this is that during melting or refining in a crucible, the atmosphere is significantly more oxygen rich than in a smelting furnace because the dimensions of the reaction vessel are less effective for building and retaining a reducing atmosphere. Often this is by design, as in the case of fire refining, to preferentially oxidize iron and remove it as slag. Either way, the result is the generation of an appreciable quantitity of oxides. In addition, because of the proportionally larger quantities of fuel ash created in relation to the volume of slag being produced, the substantial Ca contribution from this material also results in the formation of Ca-rich minerals such as pyroxenes (Bachmann, 1982b, p. 14; Tylecote et al., 1977). This being said, crucible slags are characterized by nothing if not extreme heterogeneity, making a more specific definition than that presented above unrealistic (Rademakers and Rehren, 2015).

In the case of the assemblage from Tell Atchana the crucible slags comprise 13.13% (n=13) of the samples and can generally be divided into two types, which we can broadly consider refining slags and alloying slags. This is a far from ideal characterization, since it is entirely possible that a fragment of slag could originate from alloying bronze, but not contain any bronze or tin. In other words, the old adage that absence of evidence is not evidence of absence applies in spades. Furthermore, it is impossible to distinguish between a slag formed from simple melting and one formed by deliberate refining. The distinction between the two classes of material is drawn precisely on the presence of tin and/or bronze, whether as metallic inclusions or as distinctive tin oxides. In both cases, delafossite, magnetite, and cuprite form the primary mineral assemblage, typically with a large quantity of metallic copper and sometimes very small quantitites of copper sulfides – usually as corrosion products (Figure 6-44). Stated directly, these categories are merely for the sake of describing observed differences, but may not represent an accurate division of how these slags were produced.

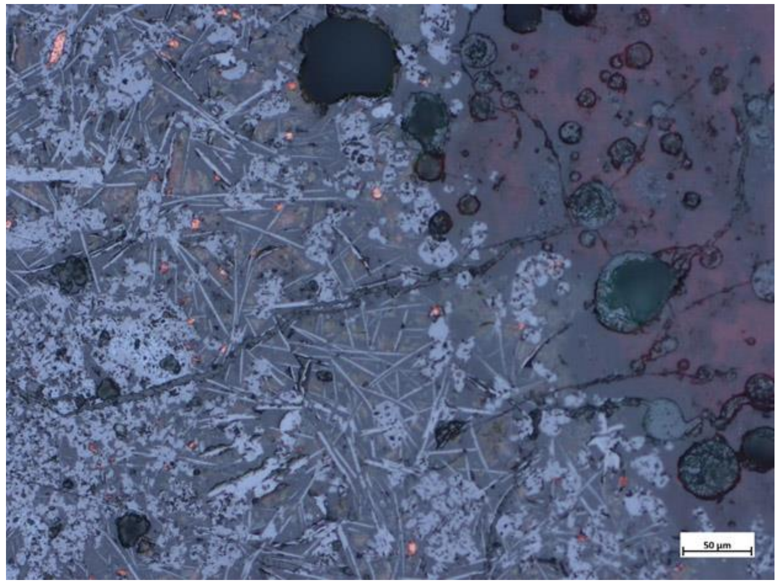



Figure 6-44: AT8680 – General view of a crucible slag showing a large region of cuprite (red internal reflections) in a glassy matrix at the upper-right corner. Moving toward the lower left, the band of spinifex crystals are delafossite in a glassy matrix highlighted by yellow disseminated cuprite. This is followed by several blebs of blue-gray massive cuprite. The lower-left corner is occupied by light gray magnetite and cuprite. Small orange spheres are metallic copper. 200x mag. Plain light.

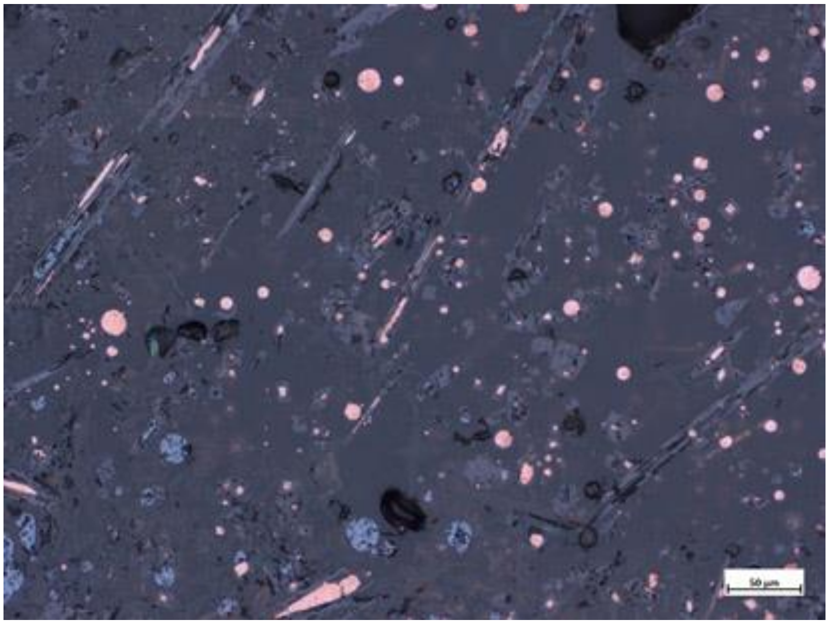


Figure 6-45: AT8491 – Detail showing acicular (needle like, medium gray) grains of tin oxide, often hosting a copper eutectic that appears as a dot or streak in the middle of the grain, depending on the plane it was cut along. The transverse section is often square. Blue globules are cuprite while orange globules are metallic copper. 200x mag. Plain light.

The so-called alloying slags are differentiated from the refining slags by the presence of acicular crystals of tin oxide ($SnO_2$) and metallic prills displaying a variety of Cu-Sn phases into the range of ~55 wt.% Sn. Regarding the actual method of alloying, it is difficult to say much beyond stating that many of these were formed through the addition of a tin-rich material to the melt. Whether this was cassiterite, a Sn-rich master alloy (see above), or pure tin metal cannot be readily discerned. While there has been some discussion in the literature suggesting that the presence of $SnO_2$ crystals is indicative of alloying through the addition of cassiterite, Rademakers has shown that this is a gross simplification of the situation and that such crystals are often an indication of nothing more than the oxidation of tin from the melt (Rademakers et al., 2018a; Rademakers and Farci, 2018; Renzi and Rovira-Llorens, 2016) (Figure 6-45).

In the case of the material from Atchana, if we can link these slags to any of the material discussed above, it would be most closely related to the alloying method reflected by AT4007, as opposed to the apparent co-smelting method seen in AT4048_1. The reason for this hypothesis is that AT4048_1 appears to have been formed under reducing conditions prevailing during a co-smelting operations, which would tend to minimize the formation of tin oxide. Meanwhile, AT4007 was likely made through the addition of a tin-rich master alloy that made have been produced in a similar process to AT4048_1. As will be discussed further in chapter 7, although these two samples show significant similarity in their trace element patterns, suggesting a close relationship, their microstructural characteristics suggest two different modes of formation. Nevertheless, any link between these metal objects and the slags discussed must remain tentative.

#### *6.2.9 Speiss*[20]

As a class of material, speiss is relatively simple to define, being an intermetallic compound – or assortment thereof – composed most frequently of arsenic or antimony (sometimes both) and iron. It is typically considered a detrimental byproduct of smelting arsenic rich ores, being particularly reviled in medieval silver smelting literature for its tendency to absorb precious metals, but also copper and some other base metals. Within the archaeometallurgical literature, its presence has been noted in contexts as divergent as an Early Bronze Age copper smelting site in Iran and Roman period silver smelting sites in Spain (Craddock et al., 1987; Doonan et al., 2007, p. 109; Kassianidou, 1998; Mehofer, 2016; Rehren et al., 2012; Thornton et al., 2009). When considered in reference to prehistoric contexts, the discussion is most typically focused on the possible use of speiss as an alloying agent for the production of arsenical copper. Within the Anatolian context, I am aware of only two other

[20] Aside from being one of the most interesting materials in the Alalakh assemblage, speiss also provides the opportunity for any number of ingenious puns – speiss up your life, speiss of the orient, sugar and speiss, speiss'ing things up (Johnson, 2020), speiss a dish with love and it gives someone arsenic poisoning, he who controls the speiss controls the universe, speiss girls, speiss is life.

studies that note the presence of speiss (Boscher, 2016; Mehofer, 2016). However, given the finds from Alalakh, as well as some fully corroded examples from Kültepe[21], I would suggest that this is due to research bias, rather than any actual lack of the material in the archaeological record.

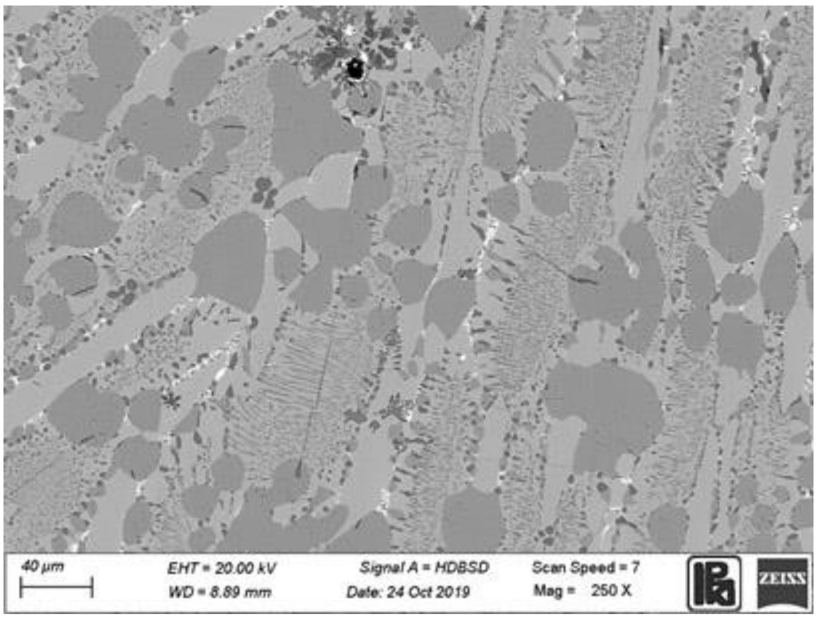



Figure 6-46: AT19597 – BSE image of the general structure. White areas between medium gray laths of $Fe_2As$ constitute the tin rich phase. Large, medium gray blobs are metallic iron, while dark gray areas are typically FeS. The eutectic is generally a mixture of FeS, FeAs, and α-Fe.

Regarding Tell Atchana, the few pieces of speiss we have analyzed thus far present an exceptionally complex picture that suggests its role as a smelting byproduct and potential alloying agent involved in the production of both bronze and precious metals. In addition to three pieces of speiss (AT19597, AT6393, and AT4048_3), AT4109_2 – a fragment of workshop floor – also contains a substantial inclusion of corroded speiss. In terms of general characteristics, all samples display a microstructure dominated by laths of iron arsenide, typically with a composition of $Fe_2As$, as well as a eutectic phase often composed of FeS or metallic iron (fig. 48). Both of these materials also occur as large dendrites in variable proportions. Often between the laths of $Fe_2As$ another discrete phase composed of Sb, Sn, As, Cu, and Fe can be observed. Finally, in several samples it is possible to observe

[21] These have been briefly studied by the author and will be presented in a later publication.

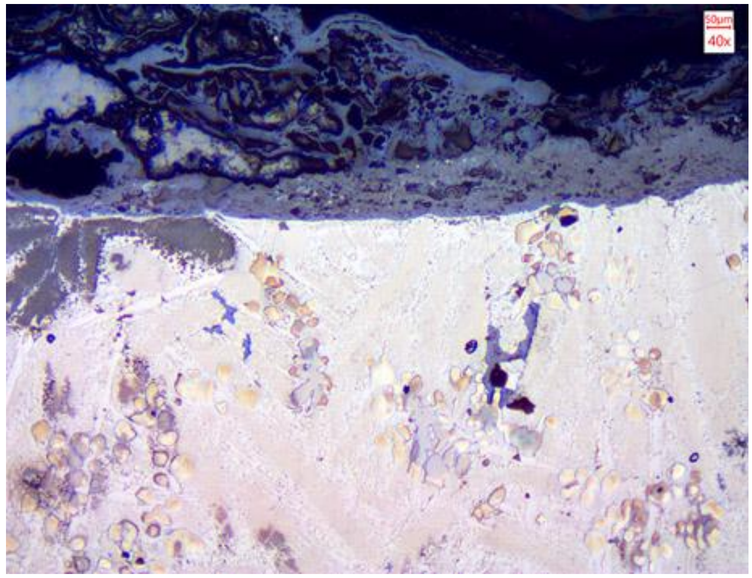



Figure 6-47: AT19597 – view of the speiss-metal interface. The clean line running across the image represents the bottom surface of the speiss layer, with the medium gray material adhering to it being lead and iron oxides. Bright spots in this oxide layer are prills of silver containing gold. Large stained globules in the main body are metallic iron, while the stippled regions are a eutectic of iron and FeS. White laths are $Fe_2As$.  40x mag. Plain light.

indications of the gravity separation mentioned by Thornton et al. (2009, p. 309), though the specific characteristics in each case tend to be unique.

In AT19597 it is possible to clearly distinguish the lower surface of the speiss layer by a large agglomeration of lead oxides along a smooth, slightly bowed surface resembling a meniscus (Figure 6-47). Within this layer, I observed a variety of silver-rich prills, some containing around 1-2 wt.% Au (Table 6-5). Similar prills could also be observed in the speiss matrix itself, sometimes with a significant content of other metals including tin. An interesting feature of the lead oxide layer at the bottom of the plate is that, upon close examination it is possible to suggest based on morphology that this material formed as a result of hot oxidation, having an idomorphic structure and small individual grains suggesting rapid cooling. If we suggest that the pool of metal beneath the speiss in this case was largely lead, which would have begun to solidify after the speiss due to its lower melting point, then oxides formed from reaction with dissolved oxygen during the cooling process would have floated to the top and become trapped against the bottom surface of the speiss. Alternatively, dissolved oxygen would rise to the top and react with lead and iron along the interface. During formation of this oxide layer, silver in solution with the lead would be left behind, forming prills

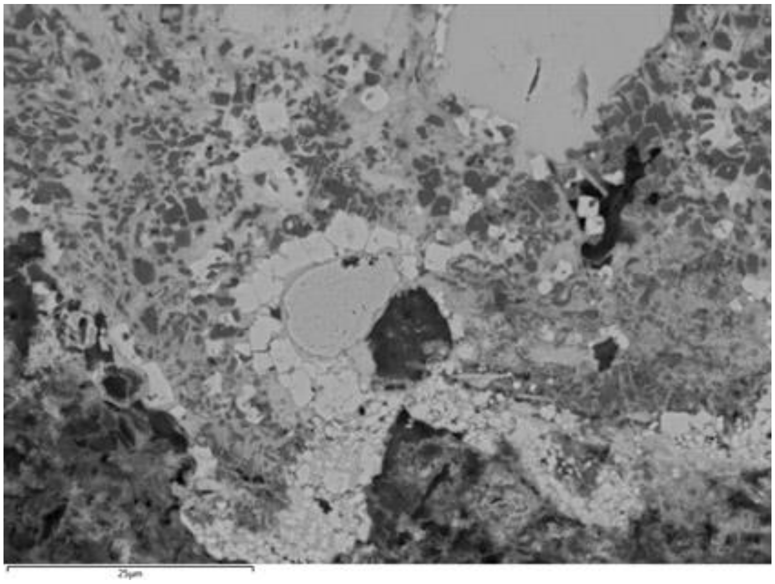


Figure 6-48: AT19597 – BSE image detailing the oxide layer at bottom. Blocky dark gray crystals are iron oxides while blocky and acicular crystals are lead oxides. The prill at middle is silver.

of silver metal via the same process as cupellation, as seen in this sample (Figure 6-48). Given this confluence of factors, we can in fact suggest that a method of washing silver from speiss using large quantitites of lead may have been in practice (Craddock et al., 1987; but see, Kassianidou, 1998).

AT6393 appears to be more closely related to the direct production of bronze than AT19597. The first indication in this respect is the clear layering at the upper surface of the sample, occupied by abundant copper sulfides (chalcopyrite, bornite, and covellite) that are frequently interspersed with a magnetite eutectic as observed in other examples of matte discussed above (Figure 6-49). Moving down into the speiss layer itself, there is the usual suite of iron arsenide, metallic iron, iron sulfide, and antimonides. However, in this case we are confronted with discrete prills, one containing approximately

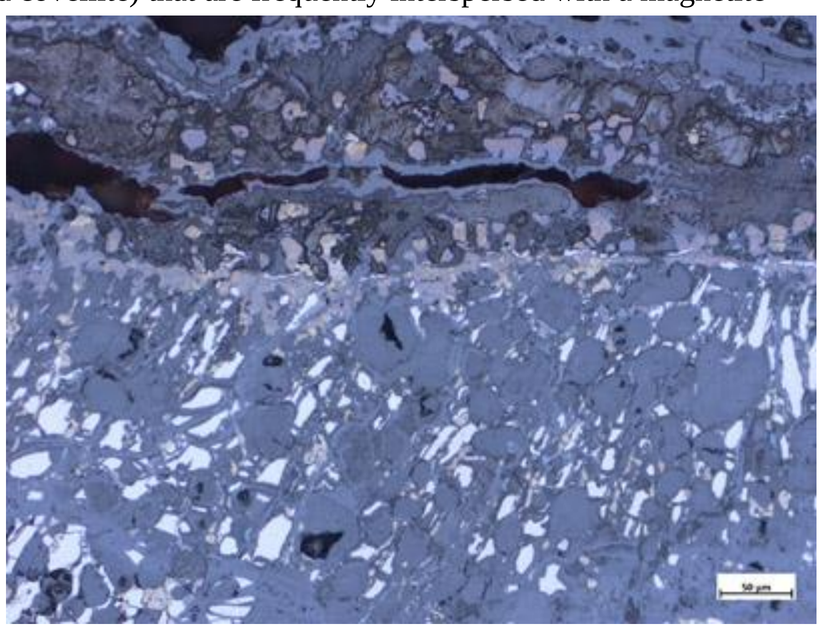


Figure 6-49: AT6393 – Upper surface of the sample showing interface with copper matte (blue, purple, yellow). Much of the speiss matrix is corroded with only fragments of Fe2As laths and a few metal prills remaining. 200x mag. Plain light.

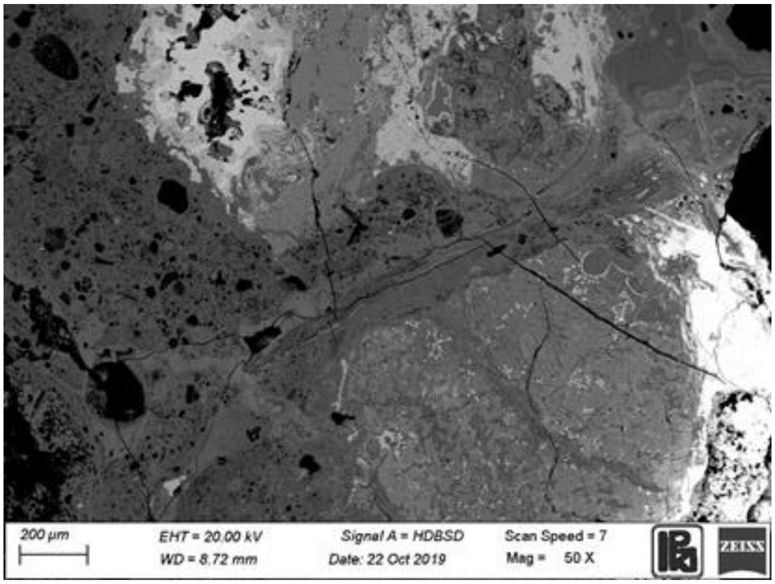



Figure 6-50: AT4109_2 – Broad overview showing an area hosting raw copper (lighter region at top) and speiss (mottled region with bright rim at bottom). The two features are not connected, however, as they are separated by dirt and charcoal and do not share connecting structures. The round features at the upper corner of the speiss are corroded prills of copper with copper sulfides (light gray) forming a halo around them.

47 wt.% Cu, 32% Sb, 8% Fe, 5% Sn, 3% As, 2% Ni, and 1% Ag (Table 6-5). While it was generally not possible to take a reliable bulk composition due to extensive intergranular corrosion, Cu appears in most phases at the ~5% level. In this case in particular, the suite of major elements is in good agreement with the partially dissolved eutectic seen in AT4007, as well as the large globule of "master alloy" seen at the top of that same sample and the speiss inclusion seen in AT4048_1. Finally, though almost completely corroded, both AT4048_3 and the speiss entrapped in AT4109_2 present the same variety of material, but without the clearly defined upper or lower surface intact. Despite its poor preservation, AT4048_3 does contain metallic prills with a composition that closely mirrors that of AT0569. With this in mind, then, we can make a strong case for suggesting that at least some bronze was being manufactured via alloying with these materials, while others were produced directly as with AT4048_1.

| AT19597 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ag-rich prills | Fe | Cu | As | Ag | Sn | Sb | Au | Pb | Sum |
| | 3.4 | 0.6 | 0.3 | 53.8 | 17.6 | 3.4 | 2.7 | 16 | 97.9 |
| | 43.8 | 1.6 | 32.4 | 12.2 | 2.7 | 4.6 | 0.1 | 2.7 | 100 |
| | nd | nd | nd | 98.8 | nd | nd | 1.2 | nd | 100 |
| | 0.9 | 1 | nd | 96.8 | nd | nd | 1.1 | 0.3 | 100 |
| FeSb | S | Fe | Ni | Cu | As | Sn | Sb | Pb | |
| | bdl | 23.8 | 0.6 | 1.6 | 11.6 | 14.3 | 47 | 0.9 | 99.8 |
| Bulk | S | Fe | Cu | As | Sn | Sb | | | |
| | 1.4 | 57.7 | 1 | 34 | 0.4 | 3.5 | | | 98 |
| AT6393 | | | | | | | | | |
| Prills | Fe | Ni | Cu | As | Ag | Sn | Sb | | |
| | 8 | 2.3 | 47.1 | 3.3 | 1 | 4.9 | 32 | | 98.6 |
| | 32 | 2.3 | 4.7 | 7.5 | nd | 5.4 | 46.5 | | 98.4 |
| | 32 | 2.1 | 5.1 | 8.3 | nd | 5.7 | 46.5 | | 99.8 |
| $Fe_2As$ | S | Fe | Ni | Cu | As | Sb | | | |
| | 0.3 | 53.1 | 0.4 | 4.5 | 37 | 1 | | | 96.3 |
| AT4048 | | | | | | | | | |
| Prills | S | Fe | Cu | As | Sn | | | | |
| | 0.2 | 1.7 | 63.1 | 0.5 | 33.2 | | | | 98.7 |
| | 0.1 | 2.3 | 63.1 | 0.7 | 32.47 | | | | 98.7 |
| | S | Fe | Ni | Cu | As | Sn | Sb | | |
| | 0.1 | 38.9 | 0.4 | 1.9 | 13.7 | 5 | 37.2 | | 97.2 |
| | 0.1 | 38.7 | 0.4 | 2.2 | 12 | 4.9 | 23.9 | | 82.2 |
| Bulk (at.% - Corroded) | O | S | Fe | Cu | As | Sb | Pb | | |
| | 59.19 | 4.15 | 14.91 | 4.58 | 12.49 | 1.48 | 3.2 | | 100 |

Table 6-5: Selected SEM-EDS point analyses for discrete phases in speiss. Results are in wt% unless noted otherwise. Results that do not sum to 100% are slightly corroded. Because the speiss from AT4109_2 was entirely corroded with no preserved metallic phases, its results were excluded. Nd = none detected, bdl = detected, but below the limit of detection (0.1%).

### *6.2.10 Workshop Floor*

Though there is only a single sample that can be clearly defined as a piece of workshop floor (AT4109_2), this section will serve as the site for a broader discussion of material that reflects directly on where particular types of activity were place and what raw materials were in use. At its most general, workshop floor is comprised of soil that became fired when droplets of molten metal fell on the ground, forming a shell around the metal. Thus, the assemblage of minerals and other material entrapped in this soil is indicative of the workshop floor at the time when the workshop was in operation. Using a similar logic, albeit with a somewhat lesser degree of certainty, the minerals found entrapped in the corrosion crusts of objects are also reflective of the floor surface at the point when that object was deposited in the archaeological record.[22]

Up to this point a variety of metallurgical processes have been explored in the assemblage from Tell Atchana, but given the mobility of metals and metallurgical products in the ancient world, many of these could have originated from any number of places and been brought to the city. After analysis of the workshop floor fragment and minerals entrapped in the corrosion crusts of some objects (Table 7-4), we can suggest with a good deal of confidence that many of the smelting and alloying processes discussed above were in fact carried out *within the city itself*. Though not unusual for alloying, this runs counter to models of smelting practice in the EBA and later (Thornton, 2009, p. 304; Van Brempt and Kassianidou, 2016, p. 551; Yener, 2000).

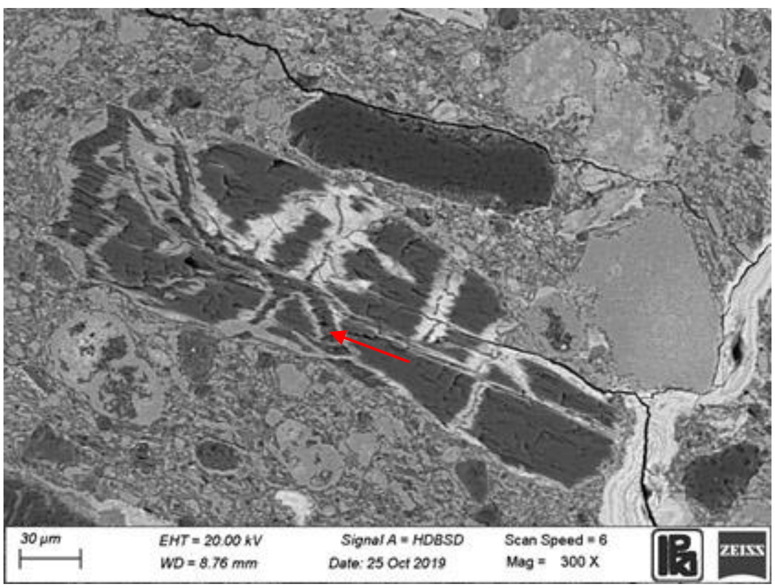


Figure 6-51: AT4109_2 – image of a enstatite grain with lead and copper minerals lining cracks as well as occurring as discrete inclusions appearing as bright regions. In the surrounding area are also granules of quartz (dark gray) hosting arsenic and copper rich inclusions, as well as small subangular grains of ilmenite (medium-light gray). The region indicated by the arrow is composed of mixed Cu-As minerals (7% Cu, 6% As, 0.6% Ni, 15% Fe, 0.1% Cr, 3% S, remainder: O, Si, Mg, Al – Results in wt%)

In the case of AT4109_2, which is represented by three samples cut from a single fragment, there is a prill of low tin bronze, one of raw copper, and one of corroded speiss (Figure 6-50),

[22] I have a very specific interest here in looking at the mineral assemblage – note, however, that significant amounts of charcoal are also entrapped in this material and represent a valuable area of study for the investigation of fueling practices.

as well as a collection of prills of ε and η bronze (Figure 6-12). In the soil separating these features, fragments of gangue material and ore were also found and subsequently subjected to point analysis via SEM-EDS (Figure 6-51). Because the subjects of analysis were essentially small inclusions within the gangue material, they should not be considered directly representative of the bulk ore being smelted, nevertheless, they are informative as to its general character. Among these minerals quartz, enstatite, olivines, and pyroxenes were present, while accessory minerals included chromite, ilmenite, and magnetite. In almost all cases it is possible to find inclusions with Cu content between 1-10 wt% and As between 1-25 wt%. The presence of sulfur is variable but not uncommon. Secondary elements in ore inclusions include vanadium, chromium, nickel, and lead in varying quantitites, while one example yielded 1 wt% tin. An important feature to note is that almost all of the gangue minerals mentioned here are igneous in nature and not native to the floor of the Amuq valley, which is characterized by extremely calcareous sedimentary rocks and soils (Gutsuz et al., 2017). This means that in all probability, these minerals were brought into the city limits over a modest distance[23], with the closest source being the Amanus Mountains to the west, particularly for chromite (Akinci, 2009; Çağatay et al., 1991; Çoğulu, 1974; Ergin et al., 2018; Parlak, 2016).

After the initial examination of AT4109_2, we began to investigate minerals and soil entrapped in the corrosion crusts of objects and found that most Area 4 material had gangue minerals associated with it. There was, however, an internal distinction where material from the west portion of the compound contained lesser amounts of metal than from east, where the furnaces were located. When examining material from Area 1, most material did not have

[23] If we ignore the Amanus and suggest the central Taurus as a source, taking the long route from Alalakh following the mountains around the edge of the Cilician plain is about a 330km trip as the crow flies. Cutting across the plain north of Adana results in a 230km trip.

associated gangue with the exception of some examples from square 42.10. The minerals found in the corrosion of AT19597, were particularly noteworthy. Though the gangue mineral assemblage is the familiar assortment of igneous minerals, the presence of quantities of barium-bearing iron arsenate as an inclusion is significant due to the association of barium with Pb-Zn ores, which often contain silver (Akinci, 2009, pp. 485–489; Pirajno et al., 2019, p. 428; Robb, 2005, p. 182). Taken in conjunction with the Ag-Au prills from AT19597, some form of precious metal processing may have been taking place in the ruins of the temple annex.

The rationale behind using this evidence lies in the fact that forced air from bellows often ejects fine particles of ore material and charcoal into the area surrounding the furnace (Rehder, 2000, p. 16). Because these minerals include quantities of heavy elements, they tend not to travel particularly far, so their dispersion should be limited to the area immediately surrounding the smelting furnaces. This has little bearing on how the ore got to the site, it merely tells us that it was smelted there, which is already a significant departure from the usual narrative deployed on the organization of LBA smelting activities (see; chapter 5). Of further importance is the distinction in the richness of analyzed ore particles, raising the possibility of functionally different spaces within the Area 4 compound. The presence of poorer gangue material in the central courtyard and adjacent rooms to the west suggests that these spaces were used for ore sorting and beneficiation. Though unanalyzed, large quantities of iron-rich quartz from the courtyard may be related to this process. This allows a working hypothesis that not only was ore being smelted on-site – the artisans here were acquiring raw ore, sorting it in-house, and smelting it on the spot.

## 6.3 Summary

In the preceding discussion, I have laid out observations made by optical and scanning electron microscopy, with supplementary data provided by EDS analyses where appropriate. As a result of these observations, I have identified several distinct classes of metal and associated production debris. In particular, I have identified a coherent assemblage of smelting and metal processing debris, contextualized by the identification of ore and gangue minerals entrapped in fragments of workshop floor and the corrosion crusts of some objects. This latter dataset further allows us to tentatively suggest that Area 4 constituted a self-contained metallurgical workshop, while Area 1 appears to have had some precious metal processing at the end of its occupation. Of particular significance is the conclusion that two, if not three, methods for the production of bronze appear to be in evidence at Tell Atchana. Finally, within the metal assemblage itself, we are able to observe a clear distinction in material types and general trends in working styles for each class of metal, with bulk compositional data supporting the material types identified via microscopy, as will be discussed in the next chapter. Due to the small sample size and its diversity, the observed trends in metalworking represent only a tentative hypothesis.

Among the smelting debris we can include four of the material classes discussed above: smelting slag, speiss, workshop floor, and hetergeneous smelting products. Among the smelting slags there are two distinct types, one being characterized by fayalite as the primary mineral species, typically occurring with a relatively small quantity of copper sulfides and large amounts of raw copper, while the other is characterized by forsteritic olivine and hercynitic spinel 2 out of 3 examples of which are associated with iron rich matte. While there is a possibility that these could represent different stages in the smelting process, it is more likely that they relate to the smelting of different batches of ore, the result in both cases being raw copper or, if AT8666 is any indication, occassionally raw copper with around 1 wt.% Sn.

Within the speiss assemblage, it is possible to suggest the presence of two different processes. The first, represented by AT19597, may be related to a method of silver production whereby Ag-rich ores were smelted in a speiss-generating process and was subsequently "washed" with substantial quantities of lead. The discovery of barium-bearing gangue material entrapped in soil adhered to this speiss fragment works in favor of this hypothesis. That it does not contain any detectable silver renders it speculative for the time being, however. The other examples of speiss can be attributed to two probable methods of bronze production. The first involves the smelting of polymetallic ores to generate a relatively low-tin bronze (~5 wt.% Sn) as seen in the case of AT4048_1. The second involves the creation of a tin-rich speiss and/or a tin-rich "master alloy" which could then be used as alloying materials in the creation of high tin bronzes, as seen with AT4007. The material referred to as workshop floor provides valuable context for the smelting activities evidenced by the slag and speiss assemblage by anchoring them into the context in which the materials were excavated. In short, the presence of low grade gangue and richer ore material as fine fragments in the workshop floor gives us a strong footing to suggest that unbeneficiated ore was brought to the site, enriched, and smelted all within a relatively limited locale.

Indications for the refining and alloying of copper are also strongly represented in the form of our crucible slag assemblage. Though it is not prudent to make any strong pronouncements on the exact process represented by a particular fragment of crucible slag due to the heterogeneity of conditions prevailing in crucibles, we have used a categorization of refining and alloying slags to facilitate discussion. The primary criteria for defining these is the simple presence/absence of tin oxides as part of the mineral assemblage, and as such the label should be taken to indicate just that. Nevertheless, many of the alloying slags also display prills of ε and η bronze, which due to their relatively purity when compared with the other alloying materials discussed above, may be taken as an indication of a third method for producing bronze involving the addition of either cassiterite or metallic tin to molten copper. Given the periodic Ni, As, and Sb contamination of these prills and the tentative relationship this suggests with the speiss, it is not currently possible to rule out the suggestion that this material was also being produced locally.[24]

Among the assemblage of metal artifacts and amorphous fragments, we have been able to clearly identify two classes of bronze, refined copper, raw copper, as well as a small assortment of other materials. As a general rule, bronze and refined copper tend to be the only materials used in the production of finished goods, though there are a couple exceptions in the form of an arrowhead and a small cutting implement made from raw copper. Between the high tin and low tin bronzes, there is a slightly greater tendency for the high tin material to be used for decorative objects while low tin was used almost exclusively for tools or other utilitarian objects.[25] Refined copper was primarily used for decorative items as well as a small number of tools and a weapon. In terms of working characteristics, 28% of tools[26] produced from high tin bronze were left in a heavily work hardened state[27] as opposed to 66% of low tin bronze tools. Of the objects produced from refined copper, only three were left in a cold worked state, none of which were

[24] Wayne Powell at SUNY Brooklyn is currently working on tin isotope studies to resolve this issue.
[25] Note, however, that due to the small relative sample size of each, this pattern may not be especially robust.
[26] We are including "shaft" fragments as part of this category since there is good reason to believe that they would be fragments of broken awls or similar implements.
[27] Meaning that the object was left in a state where grains were significantly deformed.

tools. If we consider these trends to be reliable, there are two general conclusions to be drawn. First, there is a conscious use of particular metal types for certain purposes, with high tin bronze and copper being used for both utilitarian and decorative purposes, while low tin bronze would seem to be a general utilitarian material. Second, the work regime used in the production of these artifacts seems to take into account the particular mechanical characteristics of each metal. Thus, low tin bronze is treated to maximize hardness, while refined copper is often kept in an annealed state. The working regime for high tin bronze is variable, but generally less intense than for low tin bronze.

As a general summary, I would like to emphasize the sheer diversity of processes and materials in evidence at Tell Atchana that come together to form a surprisingly coherent whole. From a systems perspective, the Area 4 compound seems to house a self-contained metallurgical workshop operated by skilled artisans with a clear understanding of each stage of the production process, from the sorting of ore to the final fabrication of objects. Using Kuijper's (2018b, p. 563) terminology, they likely fell somewhere between "common craftspeople" and "master crafters". This will be discussed further in chapter 9, where the multi-craft nature of the compound and the quality of composite artifacts produced there will become apparent. Despite a mastery of a variety of complex processes and materials, the small fragmentary slag morphology and self-contained nature of the workshop suggest small-scale decentralized activity. This is in contradiction to how textual evidence from elsewhere in the Near East is typically interpreted, with an emphasis often placed on dependent relations established through role of the palace in controlling metal resources. It does agree well with decriptions in the Alalakh archives of largely independent craft workshops, however. Finally, in light of my previous discussion of highland-lowland relations and the (in)stability of extra-city landscapes, the transport of raw ore to the city for beneficiation and smelting may suggest that the palace could not or would not protect primary production processes outside the city limits. In the following chapter, I will discuss the results from the SEM-EDS and LA-ICP-MS compositional analyses. This will help test my classifications as they have been presented here, while also furnishing data to provide nuance in the interpretation of lead isotope data.

# 7 Bulk and Trace Elemental Analysis

The analysis of elemental compositions of archaeological artifacts has a substantial history extending back to the late 18th century (Pernicka, 1999). At this point the primary concern was simply with the compositional determination of these artifacts without a specific research aim in mind. During the 19th century, attempts to utilize compositional analyses to determine artifact provenance gained prominence, albeit without significant success and heavily influenced by the project of developing nationalist narratives. With the development of more sensitive analytical techniques in the early-mid 20th century, two studies were undertaken in Germany and Austria with an eye toward defining material classes compositionally on the one hand and attempting to link those to ore deposits on the other (Junghans et al., 1968, 1960; Pittioni, 1957). Although these projects were broadly successful on the first count, defining material groups that are still generally valid to this day, the determination of provenance was largely a failure (Pernicka, 2014). This was due primarily to an ignorance of the heterogeneity of ore deposits as well as chemical changes that took place during pyrometallurgical processes. Beyond this, due to a lack of internationally recognized standard reference materials as well as a prevailing view that semi-quantitative analyses would be sufficient for the work at hand, reliable comparison of the data produced during these studies with modern quantitative datasets is not possible.

Despite the shortcomings of these earlier studies, they did begin to outline significant areas where compositional analysis could answer important archaeological questions either as an independent dataset or as a complementary component of a multivariable study. In the case of the former, the most direct use of this data is to generate material categories and identify subtle distinctions within groups. For the latter, work in the material sciences and archaeometallurgy has identified elements that remain largely constant during pyrometallurgical processes, meaning that they will maintain a consistent relationship with one another in their ratios such that they are reflective of the original ore source (Pernicka, 1999, 1986; Seeliger et al., 1985; Tylecote et al., 1977; Wagner et al., 1986). However, because disparate ore sources can often have similar trace element compositions, another independent variable is necessary for provenance determination, namely, lead isotope analysis.[1]

Within the current project, both approaches are significant. As seen in the previous chapter on optical microscopy and qualitative SEM evaluations, I generated several material categories that refer to specific technical processes and use behaviors. Through these observations, I developed a narrative of a technically competent but small-scale metallurgical system with apparently well-defined categories of material intended for specific purposes. Because this analysis was based simply on optical microscopy of the material, the categorizations may be criticized as overly subjective, given the extent to which the method relies on image interpretation. It is therefore necessary to test these findings via independent methods such as compositional analysis, which can then be treated statistically to minimize subjective bias. This provides crucial independent insights into the technological narrative I have begun to put forward by either confirming the broad characterizations I have suggested for the assemblage or highlighting alternative avenues for re-interpretation, creating a backdrop for evaluating the more idiosyncratic material.

[1] With the understanding that the reverse can also be true – at times trace elements are necessary to disambiguate lead isotope data.

Because the procurement of raw materials is a significant feature of technological systems, often tying niche industries into the broader economy (Stöllner, 2003), provenance determinations are a crucial part of this project. As seen in the previous chapter, I have already laid the groundwork to suggest that the procurement system seen at Tell Atchana is most likely local (Amanus-based) or moderate distance (Taurid) based on evidence for ore beneficiation and smelting taking place within the city itself, and even within the same workshops. Although it would be convenient to suggest based on this evidence that all the metals were produced locally, this is not a position that can be taken for granted, particularly given the emphasis on interregional trade seen in the textual record and emphasized in the archaeological literature (Pulak, 2000; Routledge and McGeough, 2009; Sherratt, 2016; Stos, 2009). By undertaking a robust study of provenance data, it should be possible to examine the extent to which locally produced or imported metals are dominant in the assemblage, which is then informative as to the scale of production and potentially even its intended consumership.

With this discussion in mind, I will present two sets of data in the current chapter. The first are bulk elemental characterizations of metals and slags as determined by SEM-EDS. This data provides an independent basis for categorizing the assemblage, separate from the data presented in the previous chapter. The second set of data will be compositional determinations made via LA-ICP-MS. The presentation of this data serves several aims. The first is to provide a complementary dataset to be used alongside lead isotope data (Chapter 8) to assist in making provenance determinations. The second is to identify trace element trends that may help to further refine sub-groupings within the categories defined by OM and SEM-EDS analysis. The third is to provide an independent check on the results of SEM-EDS analysis. Following a brief outline of the analytical methods used, I will present the statistical treatment of the SEM-EDS results as they pertain to bulk metal and slag analyses. This will be followed by the LA-ICP-MS results and their relevance to the previous discussion, as well as what they may suggest for the LIA results to be discussed in the next chapter. The evaluation of this analytical data has shown that the material categories presented previously are correct, that there are two likely modes of bronze production, and that while the bulk of the copper originated from a single source, some of the bronzes display characteristics which may revive debates of the role of tin sources in the Taurus mountains.

## 7.1 Methods

| Element | Percent Element by Weight | Uncertainty (95% Confidence) |
|---|---|---|
| **Sn** | 5.75 | 0.05 |
| **Pb** | 0.0115 | 0.0016 |
| **Zn** | 0.344 | 0.008 |
| **Fe** | 0.45 | 0.02 |
| **Ni** | 8.33 | 0.08 |
| **Co** | 0.057 | 0.002 |
| **Si** | 0.004 | 0.001 |
| **Mn** | 0.084 | 0.005 |
| **Sb** | 0.0177 | 0.0014 |
| **Cu** | 84.90 | 0.15 |
| **Ag** | 0.005 | 0.001 |
| **Al** | 0.002 | 0.0020 |
| **B** | 0.0007 | 0.0002 |
| **Bi** | 0.0039 | 0.0005 |
| **S** | 0.005 | 0.001 |
| **P** | (0.003) | - |
| **Nb** | (0.031) | - |
| **Ti** | (0.0004) | - |

Table 7-1: Certified values for standard reference material MBH 36X SP1A. Values given in parentheses are not certified and provided only for reference.

I have made every effort to make the results quantitative or at least semi-quantitative to ensure that they are comparable across different datasets. While quality assurance measures suggest that this is the case for the most part, the issue of sample heterogeneity bears brief mention (cf. Pernicka, 1986, p. 25). Because the analytical methods utilized here were intended to be minimally invasive, allowing me to preserve the epoxy-mounted samples for archiving, no acid-digestion methods were used, and all analyses were conducted on clean polished sections. While this has the advantage of ensuring that the only material being analyzed was intact metal, it also means that the results are essentially representative of a very thin (essentially 2D) slice of a larger mass of material. While this is not a significant problem for some elements such as Ni, Co, As, Sn, and others that will mix thoroughly and preferentially in copper at low concentrations (Nishizawa and Ishida, 1984; Pernicka, 1986; Saunders and Miodownik, 1990; Subramanian and Laughlin, 1988), it can be problematic for others. Key examples here include iron, which precipitates from solution beyond about 3-4% Fe in copper (Craddock and Meeks, 1987, p. 198), or Pb, which is soluble in Cu to only approximately 0.1 wt.% (Chakrabarti and Laughlin, 1984, p. 507). In both cases the distribution is essentially random, meaning that there is a chance of over or under-estimation of either component unless bulk-sampling is carried out.

In order to ensure data quality and comparability, a single standard reference material (MBH Analytical 36X SP1A Spinodal Alloy) (Table 7-1) was used across all analyses. For SEM-EDS, the standard was analyzed with three 1x1mm area analyses that were then averaged together to document accuracy of results and to monitor consistency among different analytical sessions. This procedure was carried out at the beginning of each session. Similarly, for LA-ICP-MS, five ablation points were quantified and averaged alongside the samples in each run. The choice of 36X SP1A as the quality assurance standard was influenced by two major considerations. First, the structural heterogeneity of the standard is significant enough that the generation of accurate analyses from this material should serve to improve confidence in the analysis of structurally heterogeneous archaeological materials in small volumes. Second, the provision of analytical values for provenance-related minor and trace elements (Co, Ni, Zn, As, Sb, Ag) (Pernicka, 1999, 1986; Sabatini, 2016) as well as modest contents of major elements (Sn, Ni) relevant to the Tell Atchana assemblage, made it a particularly attractive option. Moving forward, however, the use of matrix-matched standards with a broader range of trace elements would be ideal.

SEM-EDS analysis was conducted using a Zeiss Evo scanning electron microscope with operating parameters of HV = 20kV, iProbe = 1nA, Working Distance = ~8.5mm. In the case of metals with substantial corrosion, a series of smaller areal analyses were used on regions of intact metal that combined to cover a similar aggregate area. Note, however, that for as-cast tin bronze samples the error in this type of result is higher due to coring and segregation, and preferential loss to corrosion of low-tin core material. For completely corroded samples, a single area analysis was used for a simple presence/absence assessment of alloying components such as tin. Quantifications of metals were calculated as weight percent metal, while the values for slags are provided in oxide percent.

For LA-ICP-MS analysis, a set of 20 samples was initially run at the Field Museum (FM) in Chicago. This was meant to provide a set of results from a lab with experience in laser ablation of metal samples against which I could compare my results from work at the University of Illinois Urbana-Champaign Geology Department. This presented an ideal opportunity to conduct inter-laboratory testing of a selection of samples, as well as to directly compare the performance of two different laser systems. At both locations a Thermo Scientific iCAP Q quadrupole ICP-MS was employed for sample analysis. At the FM a New Wave UP213 Nd:YAG (213nm) laser system was used for solid sample introduction, while at UIUC a Teledyne Analyte Excite excimer (193nm) laser ablation system was used. At the FM, an in-house standard operating procedure was utilized. However, due to differences in

| Parameter | New Wave UP213 | Analyte Excite 193nm Excimer |
|---|---|---|
| **Energy Set Point** | | 3.5 |
| **Laser Energy** | 40% | 50% |
| **Fluence (J/cm$^2$)** | | 3.49 |
| **Rep Rate (Hz)** | 20 | 25 |
| **Spot Size (µm)** | 55 | 65 |
| **Dwell Time (s)** | 60 | 60 |
| **Shot Count** | | 700 |
| **Helium Flow (LPM)** | | 1 |

Table 7-2: Laser operating parameters.

ablation behavior between the two laser systems, a series of experimental runs had to be conducted at UIUC to determine the ideal parameters for metal ablation with the 193nm system. The settings for each can be seen in Table 7-2. Percent difference between the two datasets on the primary elements of concern (Fe, Co, Ni, Cu, Zn, As, Ag, Sn, Sb, Pb, and Bi) ranged between median values of 0.8% for Cu and 78% for Zn (cf. appendix 4).

Due to the extreme heterogeneity in many of the slag samples, we decided to exclude these from LA-ICP-MS sampling since it was highly unlikely that any of our results would yield a representative composition. As such, trace element values are available only for those samples comprised of largely intact metal. In a few instances, larger prills of metal entrapped in slag were also analyzed but are not generally included in the discussion here since they exhibit an extremely wide degree of compositional variation. In addition, results for samples with significant intergranular corrosion should be considered with caution.

Standard procedure in each case involved the ablation of five points on the freshly polished surface of each mounted sample, with an exception being made for particularly heterogeneous samples, which were subjected to ten ablations. Ablation locations were essentially chosen at random, the only true criteria being that the area be intact metal. Where intergranular corrosion was present, areas with the largest intact grains were selected and, if possible, individual grains were ablated. Quantification was carried out according to a multi-standard method adapted from that described by Gratuze (1999)[2] utilizing the average of the five measurements corrected with blank measurement values. Eight standards intended to provide the

[2] My deepest gratitude goes to Laure Dussubieux at the Field Museum for taking the time to introduce me to laser ablation methodology and quantification procedures. The quantification procedure used here is identical to that used for the Field Museum results (Dussubieux et al., 2008).

largest possible number of elements in a wide range of concentrations were used: B10 and B12 from Centre de Dévelopement des Industries de Mise en Forme des Matériaux, France, 71.32-4 and 51.13-4 from the Bureau of Analysed Samples Ltd, England, SRM500, C1123, and 1275 from the National Institute For Standards and Technology, USA, and 32X SN3G from MBH Analytical, England. Quantitative results were obtained for 15 elements $^{52}Cr$, $^{55}Mn$, $^{57}Fe$, $^{59}Co$, $^{60}Ni$, $^{65}Cu$, $^{66}Zn$, $^{75}As$, $^{82}Se$, $^{107}Ag$, $^{114}Cd$, $^{120}Sn$, $^{121}Sb$, $^{125}Te$, and $^{208}Pb$ (see also; Dussubieux et al. 2008, 646). Results for $^{209}Bi$ may be considered semi-quantitative while $^{27}Al$ and $^{31}P$ should be considered as reference values only, due to their greater deviation from the certified values for the quality assurance standard 36X SP1A.

Limits of detection (LOD) were determined by running ten blanks alongside five ablations of each of the standards. The 3σ value of the blanks was then quantified in relation to counts of $^{65}Cu$ from SRM500 (99.7% Cu), averaged from the five ablations. Best practices would typically dictate that a pure copper standard be used for LOD determination, unfortunately none was available. Under the given circumstances, these values essentially provide a rough order of magnitude below which a signal may not reasonably be distinguished from background noise. LOD were primarily at the sub-ppm level, ranging from 12ppb for Pb to 760ppb for Ni. Notable exceptions were 6ppm for As, 3ppm for Fe, and 1ppm for Te. Reproducibility of results can be evaluated according to the relative deviation between 8 measurements of 36X SP1A over the course of two weeks, yielding values well below 1% for all elements (max=0.0554% RSD for Sn, min=0.0002% RSD for Te). Finally, the accuracy of results is the percent error between the average of the 8 measurements of 36X SP1A and the certified values, with the maximum being 94% for Al, and the minimum being 0.01% for Ni. For those elements where a certified value is not available, the results should be considered merely as guidance figures.

Ultimately the types of information to be gained from SEM-EDS and LA-ICP-MS analysis are highly complementary. Though SEM-EDS has significantly higher limits of detection, often being somewhere around 0.1 wt.% (Reed, 2005, p. 142), the capacity to selectively measure larger or smaller areas with greater spatial accuracy and the ability to detect elements such as S and O with reasonable reliability makes it an exceptionally useful tool for technical analysis. Due to higher detection limits, however, most of the elements that can be analyzed are related more closely to technical processes (i.e. the development of metallic iron, retention of sulfides, or addition of alloying agents) than elemental characteristics deriving from the composition of the original ore material. As such, not only can the two sets of results serve as a check on one another since the determination methods are theoretically completely independent, they also serve to fill in the “blind spots” of the opposing method.

## 7.2 SEM Results

### *7.2.1 The Metals*

The purpose of the SEM-EDS data is primarily to characterize the assemblage according to factors related to technical processes. Though the elements seen here, with the general exception of tin, are related to the character of the original ore, their variation is controlled by roasting, smelting, refining, and alloying processes. As can be seen in Figure 7-1, Principal Component Analysis (PCA) of SEM-EDS results for the metals assemblage strongly support the typology developed based on optical microscopy. The only modification that the SEM-EDS results necessitated to that typology was the creation of low-Sn and high-Sn categorizations.

Looking at the PCA loading plot in Figure 7-1, the trend characerizing Raw and Refined Copper illustrates an inverse relationship between Fe and S on the one hand, and As on the other. In the raw copper and heterogeneous smelting product (HSP) categories, what this reflects is a retention of elements that typically exit metal systems via oxidation due to their creation under highly reducing conditions, with the loose clustering of this field reflecting the significant compositional variation of these samples.

Given that all three elements are typically susceptible to oxidation, the loss of iron and sulfur, and increase in arsenic descending into the refined copper field is counter-intuitive. In this case, it is necessary to examine the SEM-EDS data for Fe vs. As more closely (Figure 7-2), which provides a nuanced picture of the processes in action, with a negative relationship

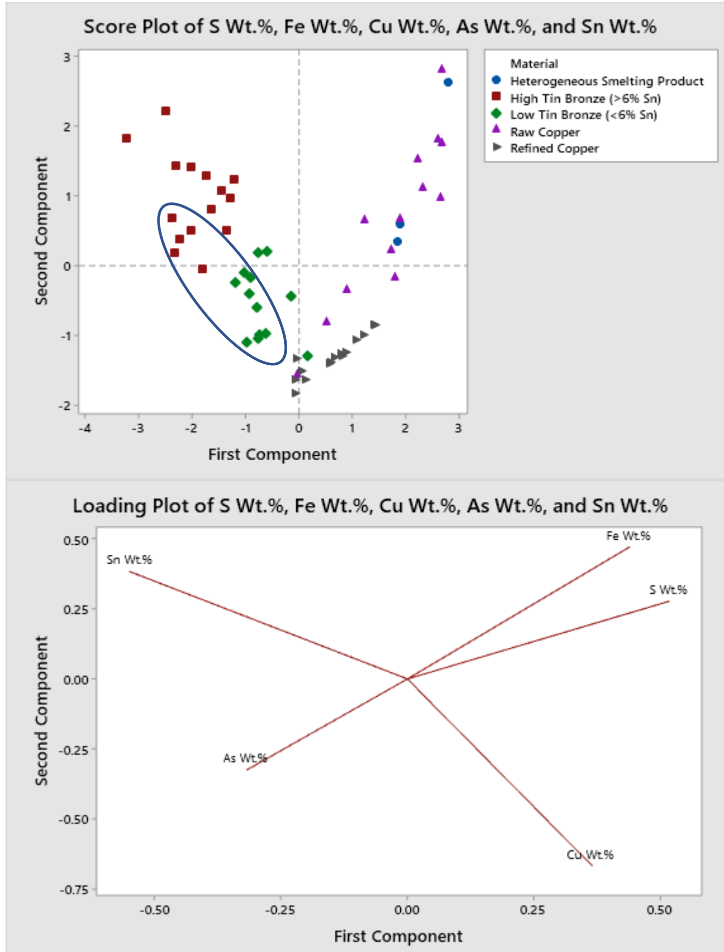



Figure 7-1: Upper: Score plot for the SEM-EDS results of the metal assemblage. The bronzes in the blue circle correspond to the high-As samples discussed below. Lower: Loading plot for SEM-EDS data of the entire metal assemblage. The angle between two lines indicates the relative degree of correlation between the two variables, with acute angles indicating a stronger relationship.

prevailing until approximately 1% iron and 0.8% arsenic, after which they become positively correlated. The negative portion of this trend may be due to the substantial affinity of arsenic for copper, causing its loss to decrease exponentially with lower concentrations, while oxidative loss of iron remains largely constant across all compositions, resulting in a minor uptick in arsenic concentrations (Merkel, 1982, p. 338; Sabatini, 2016, pp. 61, 70). Nevertheless, the loose

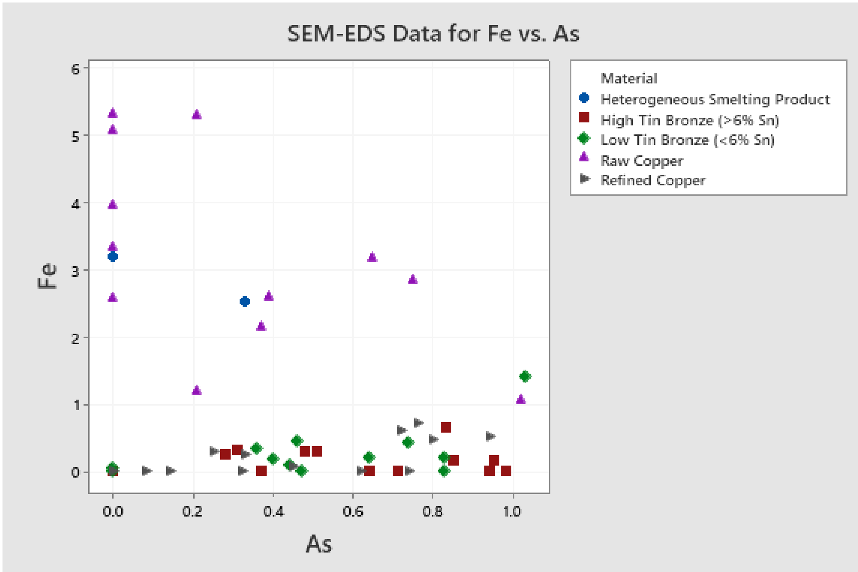



Figure 7-2: Scatterplot of Fe vs. As using SEM-EDS results. The cluster of bronzes to the right of the 0.6 mark generally correspond to those materials identified as speiss related in chapter 6.

clustering in this part of the graph, reflecting compositional variability, and the relative weakness of the relationship suggests that another process is at work. The solution may lie in the tendency for sulfur to facilitate the loss of arsenic from copper melts, with both having the potential to be reabsorbed by the melt with decreasing temperature (Sabatini, 2016, pp. 70–71). Given the range of independent variables involved (slag cover, redox conditions, temperature variation) in moderating this process, the seemingly amorphous relationship between arsenic in sulfur in the SEM-EDS data (Figure 7-3) would seem to support this assertion. This would mean that while sulfur is being lost through oxidation and volatilization (but partially

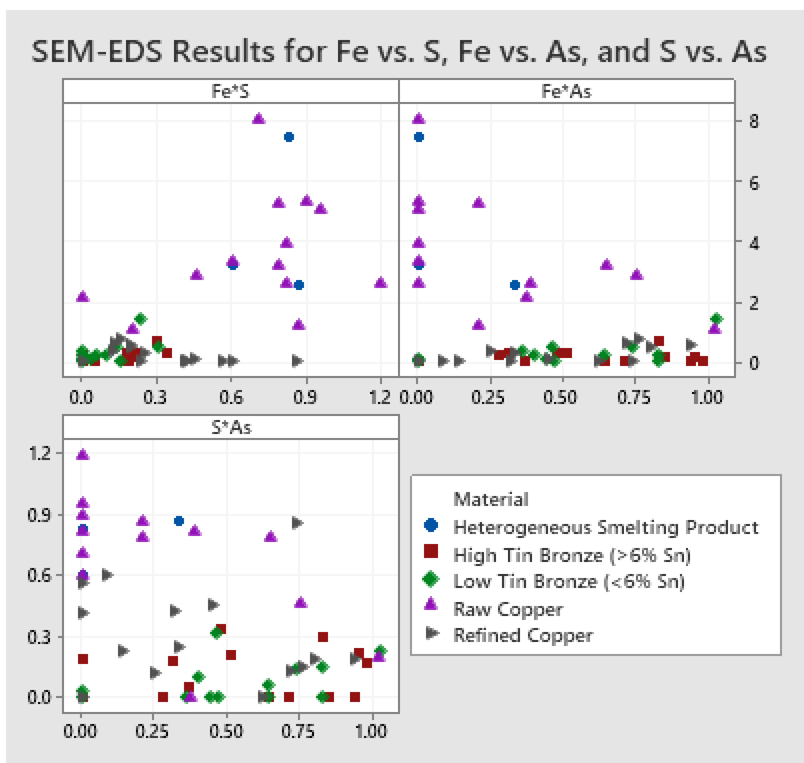



Figure 7-3: Biplots for Fe vs. S, Fe vs. As, and S vs. As

reabsorbed) and iron is leaving the system through oxidation, arsenic, with decreasing rates of both processes as well as potential for reabsorbption, may increase slightly. In this case, the PCA results primarily reflect the negative Fe-As relationship and the positive Fe-S relationship, rather than a truly inverse relationship between Fe and S on the one hand and As on the other. The positive relationship between 0.8 and 0 wt.% As in Figure 7-2 is then characterized by the comparatively straightforward loss of both iron and arsenic (as well as sulfur) under oxidizing conditions prevalent during refining (Sabatini, 2016, pp. 84–86).

For the tin bronzes, the patterning seen in Figure 7-1 is generally predictable, reflecting the division established at around 6 wt.% Sn with reasonably tight clustering. Considering the discussion in chapter 6 on the potential involvement of speiss or speiss-generating processes in the production of tin bronzes, the slightly positive relationship between arsenic and tin suggested by the loading plot is worth investigating, since the addition of tin-bearing speiss to copper or the smelting of tin-bearing arsenic rich ores would lead to a correlation between the two. Among the absolute SEM-EDS values (Figure 7-4) for these elements there is little indication of a trend. At most, there are three amorphous groups moving left to right, with one group containing no arsenic, another containing between approximately 0.3 and 0.45% As, and the third containing between 0.7-1% As. This final group includes all those samples which were identified as being associated with speiss, which does at

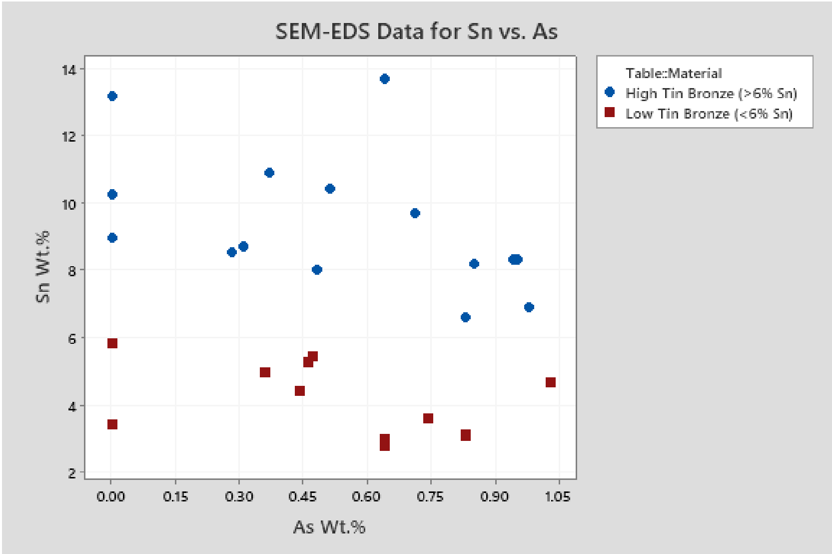



Figure 7-4: SEM-EDS values for Sn vs. As

least associate high arsenic values with relatively unpredictable tin contents as might be expected from relatively uncontrolled co-smelting of Cu, As, and Sn ores. Nevertheless, the score plot (Figure 7-1) does illustrate this distinction by a slight break running from upper left to lower right with the high-As group being circled in blue. Though this provides some hints of distinction between these groups, the minimal differentiation between them – a mere 0.2% As – is not satisfactorily convincing. However, as will be seen in the LA-ICP-MS data below, the rough contours are generally correct.

With this and the preceding discussion in mind, when we move across the plot in Figure 7-1, we are seeing a decrease in iron moving clockwise from top right to bottom center over the course of the production process. There are then two groups representing refined copper, one slightly to the right with As below about 0.5%, and another at approximately 0.7% As, slightly to the left. Continuing in clockwise fashion, the upward trend is characterized by increasing tin content, with a slight bimodal distribution based on arsenic content. The lower portion of the bronze distribution (circled) represents the high-As distribution in the far right of Figure 7-4.

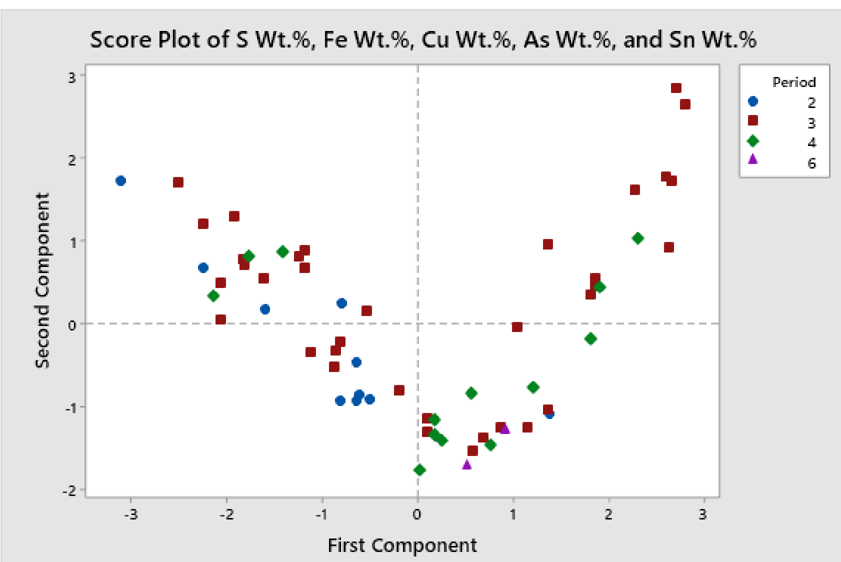


Figure 7-5: Score plot for SEM-EDS data of all metals with points defined by period.

From a chronological perspective (Figure 7-5), several general observations are possible. First and foremost, a distinct majority of metallurgical debris and products originated during Period 3 in the LBI-II transition, covering all classes of metals with a clear prelude in Period 4, the LBI. For Period 2, during the high point of the Hittite occupation of Alalakh (Yener et al., 2019b), no raw copper is present, and only a single example of refined copper, with the assemblage being composed almost exclusively of tin bronzes. Given that the latter period is characterized by the construction of the Northern and Southern Fortresses and a more substantial imprint of state power across the site, it is debatable whether this trend indicates a cessation of primary production in the city. Though this is certainly one option, an equally probable explanation is simply that the locus of production moved and may have been forcibly centralized or even relocated by the new administration, meaning that we have just not excavated this part of the assemblage for this period (also, see the discussion on the distribution of finds for 64.94 in chapter 9). Indeed, this is my preferred hypothesis given the substantial changes that occurred after the assumption of Hittite control.

In sum, what the bulk SEM data for the metals represents is a general confirmation of the trends and categories discussed in chapter 6, lending support to the delineation of several distinct categories of material. This, in turn, supports the associated conclusion that each class of material seems to have had a more or less defined set of uses, at least in as far as an assemblage of this size can be considered representative. I would suggest that this type of material specialization (cf. Kuijpers, 2018b, p. 554), based on long-term experience with materials of often subtle variation, is itself a signifier of substantial systemic specialization. Examined chronologically, this pattern appears to have characterized a house-based mode of production in the metallurgical industry at Tell Atchana for at least a century, with probable roots slightly earlier toward the LBI-MBII transition. At present, our data for the beginning of this segment of time is lacking, being limited to three fully corroded fragments. One of these, however, does show structures that can be convincingly linked to the category of raw copper. Once we move into the Hittite occupation (Period 2), this long-term pattern of production is disrupted, while the technological system and specialization behind it is either co-opted or completely erased by the new authority.

### *7.2.2 The Slags*

Although the bulk analysis of slags generally allows for the definition of several categories and trends, the contours of these groups are somewhat more ambiguous than those developed for the metals within this assemblage. This is an issue that is widespread in studies of ancient slags, primarily due to significant variability in conditions during a single smelting operation as well as between smelting events (Bourgarit, 2019, p. 208; Crew and Rehren, 2002, p. 87; Erb-Satullo et al., 2014, pp. 150–151; Hauptmann, 2011, p. 190; Humphris et al., 2009). In this case the issue is compounded further by the small sample size (n=20), particularly for smelting slags. Nevertheless, the bulk data support the classifications made earlier based on microscopic analysis, though there are at least a few deviations. With this in mind, I will continue to use the crucible/refining vs. smelting slag terminology laid out in chapter 6 and the symbology used on plots will also reflect these classifications, even if they should be taken as indicative and less firmly grounded. Finally, as a general comment, in all plots displaying slag analyses, the plots labelled as HSP refer to values from the bulk analysis of smelting slag adhered to these samples.

The most immediate feature to note is the variation in metal oxides between the two groups. Among the crucible slags, the mean copper content (as CuO wt.%) is approximately 11% with a standard deviation of 7% and maxima and minima at about 2% and 22% respectively. By contrast, the mean copper content of the smelting slags is ~6% with a standard deviation of around 3% and maxima and minima at ~11% and ~2%. In the case of this latter group, these numbers are skewed by a small handful of samples, one being AT8019, which is composed of partially fused material and contains significant metallic copper (see; Chapter 5 for a discussion of this sample), while the others are samples of partially processed material containing large amounts of copper matte. When looking at the HSP samples in this category, two have copper contents of 5-6%, while the other two have 2-3%. Though comparable to the slags from Kalavassos (Van Brempt and Kassianidou, 2016, p. 550), by the standards of Early Bronze Age slags from Crete and the Levant, with copper contents ranging between 2-5 wt.%, the values of the former samples are rather high, being more comparable to EBA copper slags from Shahr-i Sokhta in Iran (Bassiakos, 2006; Gale et al., 1985a; Georgakopoulou et al., 2011; Hauptmann, 2007, p. 182; Hauptmann et al., 2003, p. 202). Looking at later material from the LBA and EIA of the Caucasus, even the lower copper examples at Tell Atchana are still elevated, with many of the Caucasian slags showing <1 wt.% Cu, despite all other aspects of slag composition being closely comparable (Erb-Satullo et al., 2014).

There are two explanations for this elevated copper content in the smelting slags. The first is that, because many of these slags derive from the slag-metal interface, there will automatically be a higher copper content where the metal was unable to completely sink through the slag layer prior to cooling. The second is that, as seen in the microscopy and confirmed by the high sulfur content (~1.5 wt.%, expressed as $SO_3$) of these slags, much of the copper is present as matte phases. Due to their lower density compared to metallic copper, these phases are generally slower to descend through the slag layer, being more likely to become entrapped before being reduced to metal (Thornton et al., 2009, p. 309).

The same distinction in slag types prevails in terms of other metal oxides as well. For $SnO_2$, we can make the rather elementary observation that this is found only in the crucible slags.

However, the oxide analyses are somewhat misleading in that all the tin-bearing slags also host metallic inclusions with compositions up to 50 wt.% Sn. This is an important detail to consider insofar as it is suggestive of active alloying of bronzes as opposed to simply melting existing bronze objects for recycling (Crew and Rehren, 2002, p. 89; Rademakers et al., 2018b, p. 1663, 2018a, p. 517; Rademakers and Farci, 2018, p. 350). Arsenic was found above the detection limit in only two crucible slags, however, point analyses of metallic copper inclusions in almost all crucible slags yielded arsenic contents between 0.7-4%, with a median of 1.3% - well above the arsenic value for most raw and refined copper in the assemblage. Given the affinity of arsenic for copper, as well as the tendency for oxidized arsenic to be reabsorbed by metallic copper at lower temperatures (Sabatini, 2016, pp. 70–71, 84), this is not entirely surprising. As arsenic was removed from the main bulk of the melt in the crucible as oxides and vapor, some would become entrapped in the slag. During the cooling process, a portion of this material would be absorbed by small droplets of metal entrapped in the slag, resulting in significant enrichment of these small volumes of metal. The remainder would then be oxidized by sulfur at lower temperatures (~700°C) and degas as $AsS_{(g)}$ (Sabatini, 2016, p. 84). Finally, we may also note that a significant number (n=7) of the crucible slags also contain quantities of CoO up to 1 wt.%, often appearing as a component of magnetite. In either case, the argument to be made is that crucible slags are characterized by a significantly higher content of metal and metal oxides. In the case of the former, this is due largely to the higher viscosity of the crucible slags, preventing separation between slag and metal (Hauptmann, 2014, p. 24), while the latter is determined by the more oxidizing conditions of crucible operations (Bachmann, 1982a, p. 16; Rademakers and Rehren, 2015, p. 589). Meanwhile, the more reducing atmosphere during smelting slag formation combined with less viscous fayalitic slag compositions would result in mitigated loss of metallic elements to slag due to oxidation and physical entrapment (Bachmann, 1982a, p. 10; Rehder, 2000, pp. 108–112).

Considering the major element compositions of the slags (Bachmann, 1982a), a few general trends can be comfortably identified and explained when considered in light of regional clay source studies and the gangue analyses mentioned in the previous chapter. While there are a few exceptions, the distinction between smelting slags and crucible slags holds true when plotted in the ternary system

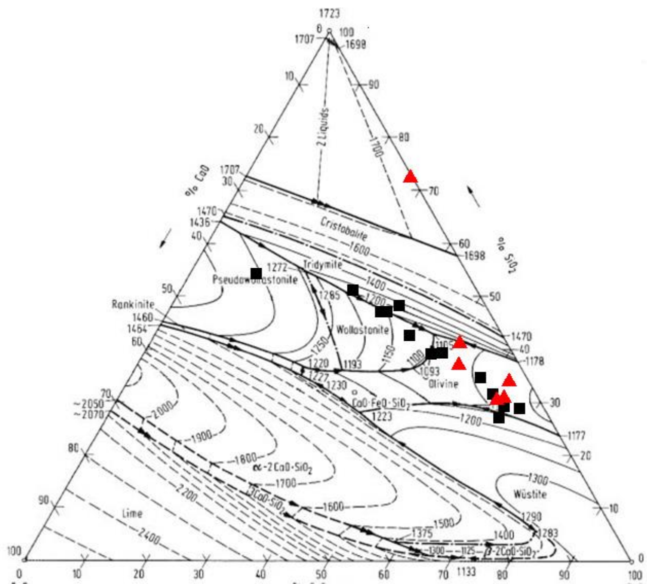



Figure 7-6: Ternary phase diagram for the system $SiO_2(+Al_2O_3)$-$CaO(+MgO)$-$FeO$. Crucible slags are plotted as black squares while smelting slags are plotted as red triangles.

$SiO_2(+Al_2O_3)$-$CaO(+MgO)$-$FeO$[3] (Figure 7-6), with the smelting slags[4] plotting to the lower melting (~1,100°C) regions of the fayalite field while the crucible slags show a distribution from the fayalite field through the more calcium-rich wollastonite and pseudo-wollastonite fields. Plotting the data in the ternary system $SiO_2$-$FeO(+CaO, MgO)$-$Al_2O_3$ (Figure 7-7) illustrates the slight variation in alumina content that resulted in the formation of hercynite in samples AT18636 and AT4327, which can be seen at the borderline between the fayalite and hercynite

[3] This system typically has MnO added to FeO, however, MnO never appeared as a detectable component of the slag assemblage. In fact, when analyzing gangue inclusions, it rarely comprised more than 0.1 Wt.% of any gangue mineral.
[4] The one smelting slag seen in the $SiO_2$ field of figure 4 is sample AT8019, which contained a significant amount of unreacted gangue material, increasing its silica content and shifting it into the extremely high-melting range of the diagram.

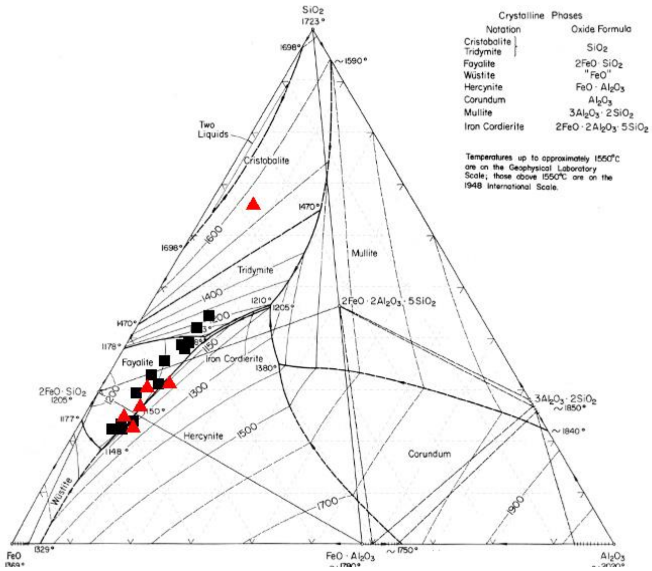



Figure 7-7: Ternary phase diagram of the $SiO_2$+FeO(+CaO, MgO)+$Al_2O_3$ system. Black squares are crucible slags and red triangles are smelting slags.

fields. What we can ultimately take from this discussion is that the primary distinguishing characteristics of these slags, aside from the previously mentioned metal and metal oxide content, is CaO and, to a lesser extent FeO, which has been diluted by fuel ash and absorbed ceramic[5].

As a rule, much of the CaO – as well as $Na_2O$ and $K_2O$ – present in slags tends to originate in the fuel ash generated by burning charcoal. According to Tylecote (1977), the maximum values for these are generally 8%, 0.4%, and 1%, respectively. $P_2O_5$ is another contribution from fuel ash, typically up to 1%. In the bulk data, there is a general bimodal distribution in the calcium content of the slags, with the smelting slags (including adhered smelting slag from the HSP group) typically showing lower values between 1-6%, while the crucible slags fall into two groups between 2-6% and 8-23%. The majority of the crucible slags, however, are between 8-13% CaO (Figure 7-8), which is generally elevated for LBA slags of this type (cf. Erb-Satullo, Gilmour, and Khakhutaishvili 2015, 266), and even somewhat high when compared to chalcolithic crucible slags (cf. Boscher 2016, 173–74) from Anatolia.

[5] Since I did not actually analyze for different oxidation states of iron, this is a general simplification for the sake of discussion. As mentioned in chapter 5, much of the iron in the crucible slags, for example, is actually present as $Fe_2O_3$.

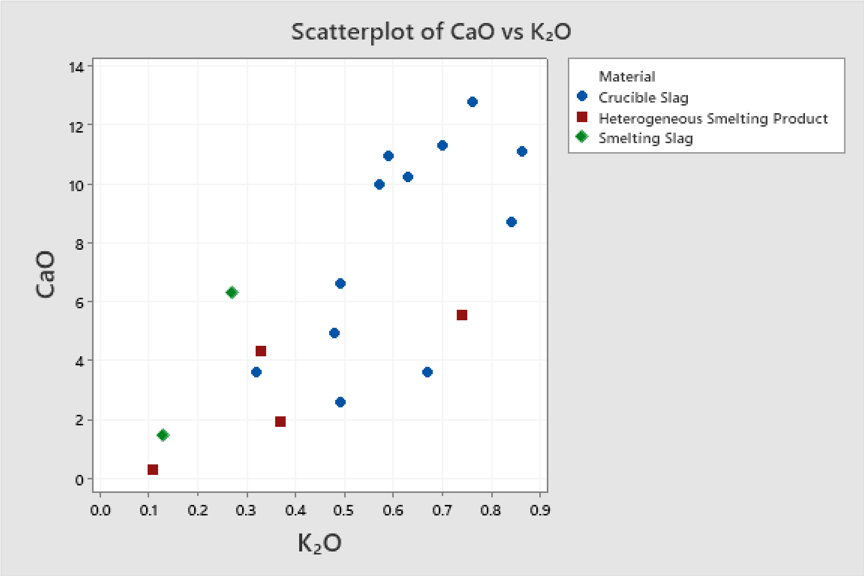



Figure 7-8: Scatterplot displaying the relationship between CaO and $K_2O$. In this and all plots representing slag analyses, heterogeneous smelting product points are the values derived from bulk analysis of smelting slag adhered to these samples.

While it is typical for crucible slags to have elevated CaO contents compared to smelting slags due to the higher fuel/charge ratio necessary to maintain temperature in a small open vessel (Rehder, 2000, pp. 89–90; Tylecote et al., 1977, pp. 310–311), the even more substantially elevated values for the Atchana slags is likely due to the very calcareous clays in the Amuq Valley (Gutsuz et al., 2017). When compared against the data of Gutsuz et al., the bulk analyses of ceramic material adhered to some crucible slag fragments (Figure 7-12, Table 7-3) shows solid agreement with the Afrin Clay Group for $SiO_2$ vs. CaO and $Al_2O_3$ vs. $TiO_2$ while the crucible material from AT19157 shows deviations for $Na_2O$ vs. MgO and MgO vs. $Fe_2O_3$. This deviation is likely due to the sample being slightly slagged, resulting in the inclusion of $Na_2O$ from fuel ash and $Fe_2O_3$ from the melt, thereby diluting the other oxides. Returning to the issue of CaO, it is worth noting that the elevated CaO content of the Afrin group, though not as high as the Orontes group, is still well above other regional sources. As such, the values beyond 8% CaO may well be due to reaction between the crucible slags and the crucible fabric. Indeed, the substantial positive relationship (Figure 7-9) between $TiO_2$ and CaO ($r^2$ = 82.7%) would seem to support this. Based on my own experimental smelting with crucibles and portable clay hearths

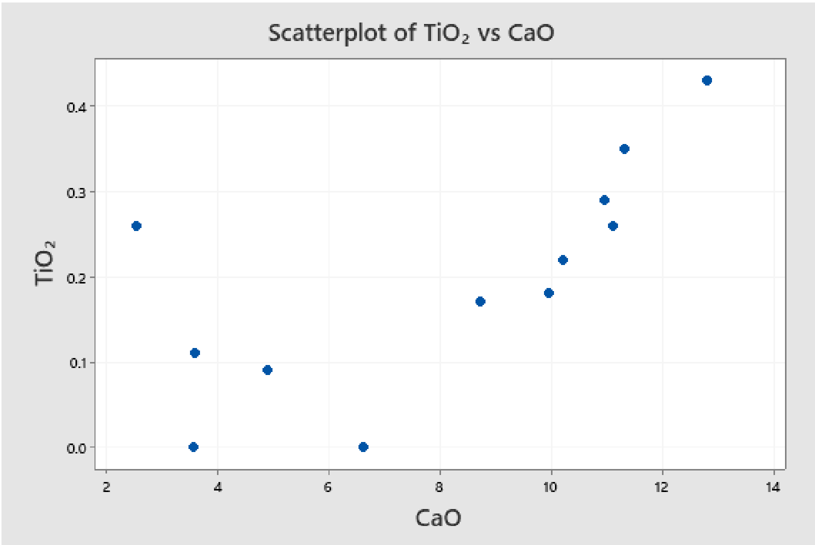



Figure 7-9: Scatterplot displaying the relationship between $TiO_2$ and CaO among only the crucible slag assemblage.

made from these calcareous clays, though these vessels will hold form and remain durable under extended exposure to temperatures up to 1200°C[6], upon cooling they frequently disintegrate into dust after a few days. So, while fragments of actual crucibles are generally lacking in the assemblage, we can see their potential effect on slag chemistry while anecdotal evidence suggests a reason for the lack of representative material.

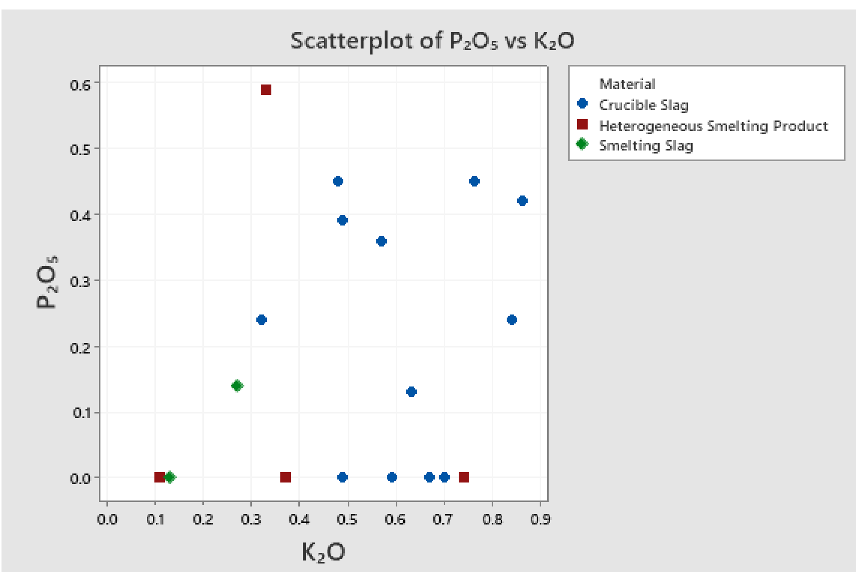



Figure 7-10: Scatterplot for the relationship between $P_2O_5$ vs. $K_2O$.

Regardless of whether crucible ceramic constituted a significant contributing factor to the bulk composition of the slags, the bimodal distribution of CaO contents is instructive. If we take CaO as being largely or solely derived from fuel ash, the much lower content in the smelting slags is indicative of more efficient fuel

[6] They may even tolerate higher temperatures, I tended to maintain these at around 1200°C, however.

use in line with the employment of shaft furnaces for smelting (Rehder, 2000, pp. 92–100). In the plots for potassium and phosphorous oxide (Figure 7-10), though the relationship is diffuse, we once again see a similar bimodal distribution where the smelting slags plot toward the left, while the higher $P_2O_5$ values of the crucible slags suggest much greater ash content, reinforcing this impression.

Examining the data for $Al_2O_3$ and $TiO_2$, which are generally used in conjunction as indicators for the absorption of ceramic material into slags (Bayley and Rehren, 2007, p. 47; Boscher, 2016, p. 176; Catapotis and Bassiakos, 2007, p. 71), the situation becomes somewhat more complicated. Figure 7-11, shows that while there is an expected positive correlation between the two, which is unproblematic for the crucible slags ($r^2$ = 60.8%), the smelting and HSP slags are less closely correlated ($r^2$ = 31.9%). Part of this is likely attributable to the small sample size, but there is also a potential explanation in the supporting data. First, the spot analyses for the ore sample from square 64.72 (AT8039), display variable values for aluminum and titanium ranging up to 31 and 18 wt.%, respectively (Table 7-5). Meanwhile, the assemblage of gangue minerals seen in the fragments of workshop floor and adhered soil

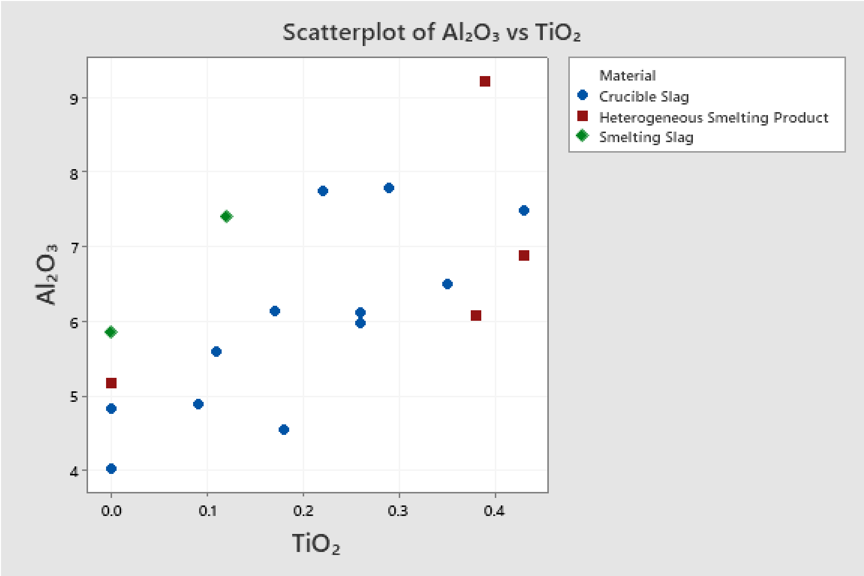



Figure 7-11: Scatterplot showing the relationship between $Al_2O_3$ and $TiO_2$. Note the large gulf between the HSP samples to the right and the smelting slags and one HSP sample on the left. The crucible slags show a consistent distribution showing a continuum for different degrees of reaction with crucible ceramic.

material (Table 7-4), hosts a range of spinels, aluminosilicates, pyroxenes, and olivines well in line with the local Kızıldağ and broader Taurid ultramafic geology (Akinci, 2009; Çağatay et al., 1991; Çoğulu, 1974; Ergin et al., 2018). Considering potential elemental contributions from such materials, the observed variation in concentration of these elements could simply be due to their inclusion in the smelting charge in varying proportions depending on the specific source and degree of ore beneficiation.

| AT Number | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $SO_3$ | $K_2O$ | CaO | $TiO_2$ | $Fe_2O_3$ | CuO |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **22869** | 0.1 | 4.2 | 12.3 | 56.6 | nd | 0.3 | 1.3 | 18.4 | 0.6 | 5.7 | nd |
| **19157** | 0.8 | 3.2 | 11.3 | 52.3 | 0.8 | nd | 0.8 | 17.5 | 0.6 | 6.7 | 5.5 |

Table 7-3: Weight % oxide compositions of ceramic adhered to two crucible slags.

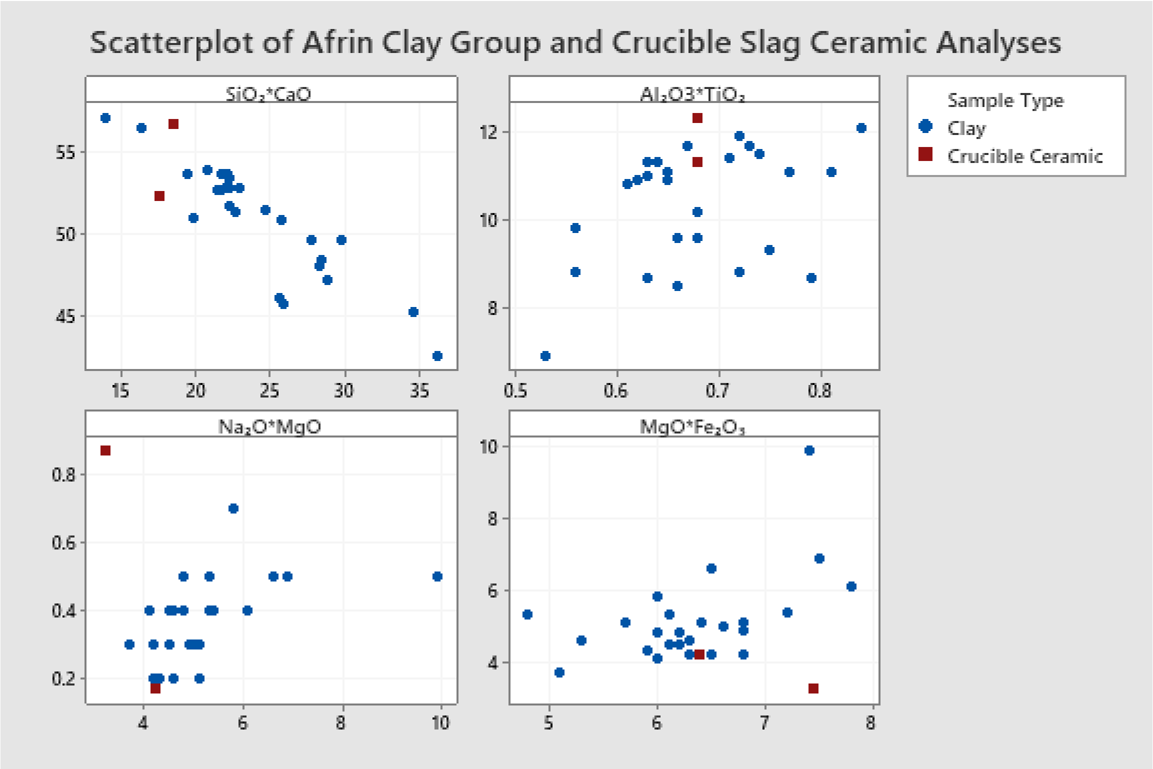



Figure 7-12: Scatterplots comparing compositions of samples from the Afrin Clay Group (blue circles) (Gutsuz et al. 2017) against two pieces of Tell Atchana crucible material (red squares) adhering to two pieces of slag. In the two upper plots, the point representing AT19157 is always on the bottom, while in the lower plots it is the outlier.

| AT Number | General Mineral | O | Na | Mg | Al | Si | P | S | K | Ca | Ti | V | Cr | Mn | Fe | Ni | Cu | Zn | As | Zr | Sn | Ba |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **AT4109_2** | Ilmenite | 57.4 | nd | 3.5 | 0.2 | nd | nd | nd | nd | nd | 19.2 | 0.3 | nd | 0.3 | 19.2 | nd | nd | nd | nd | nd | nd | nd |
| | Feldspar | 58.6 | 2.8 | nd | 13.3 | 19.6 | nd | nd | 0.1 | 5.2 | nd | nd | nd | nd | 0.4 | nd | nd | nd | nd | nd | nd | nd |
| | Enstatite | 60.1 | nd | 15.5 | 0.5 | 12.9 | nd | 0.2 | 0.1 | 0.1 | nd | nd | nd | nd | 8.4 | nd | nd | nd | 2.3 | nd | nd | nd |
| | Mixed Iron Arsenate | 60.5 | nd | nd | nd | 0.5 | nd | 5 | 0.2 | 1.3 | nd | nd | nd | nd | 15.8 | nd | 5.2 | nd | 11.6 | nd | nd | nd |
| | Mixed Spinel | 53.9 | nd | 7.1 | 11.9 | nd | nd | nd | nd | nd | nd | 0.2 | 17.6 | nd | 9.4 | nd | nd | nd | nd | nd | nd | nd |
| | Quartz | 60.8 | nd | 0.9 | 3.6 | 24.7 | nd | nd | 0.4 | 0.3 | 0.1 | nd | nd | nd | 7.1 | nd | nd | nd | 0.8 | 1.3 | nd | nd |
| **AT8040** | Ilmenite | 61.9 | nd | 1 | 1.8 | 5.6 | nd | nd | nd | 0.2 | 14.9 | 0.3 | nd | 0.2 | 11.2 | nd | 2.9 | nd | nd | nd | nd | nd |
| | Ilmenite | 58.8 | nd | 2.3 | 1.9 | 7 | nd | nd | 0.1 | 0.2 | 12 | 0.4 | nd | 0.3 | 14 | nd | 3.2 | nd | nd | nd | nd | nd |
| | Ilmenomagnetite | 51.1 | nd | nd | 2.2 | 0.1 | nd | nd | nd | 0.1 | 7.9 | 0.6 | nd | 2.4 | 33.8 | nd | 0.8 | 1.1 | nd | nd | nd | nd |
| **AT19597** | Olivine | 65.1 | nd | 6.4 | 3.1 | 13.3 | 0.2 | nd | 0.3 | 0.3 | nd | nd | nd | nd | 9.9 | 0.3 | nd | nd | 1 | nd | nd | nd |
| | Mixed Iron Arsenate | 65.2 | nd | nd | 0.4 | 1.4 | 0.4 | 5 | nd | 1.5 | nd | nd | nd | nd | 13.9 | nd | nd | nd | 8.1 | nd | nd | 4.2 |
| | Mixed Iron Arsenate | 64.5 | nd | nd | 0.5 | 1.5 | 0.6 | 4.8 | 0.2 | 2.4 | nd | nd | nd | nd | 14.5 | nd | nd | nd | 7.2 | nd | nd | 3.7 |
| **AT4309** | Quartz | 61.8 | nd | 0.5 | 2.6 | 32.1 | nd | nd | 0.5 | 0.2 | nd | nd | nd | nd | 1.1 | nd | 1.2 | nd | nd | nd | nd | nd |

Table 7-4: Selected point analyses of gangue mineral inclusions from workshop floor and adhered soil. Note that because these are analyses of discrete inclusions, two considerations must be made. (a) These are not representative of bulk ore compositions, they are reflective of the associated gangue and to a limited extent the associated ores, as such, they are merely indicative of the materials used. (b) Because a significant amount of the data here results from electron beam interaction with the surrounding matrix, while the bulk compositions are roughly indicative of the types of mineral present, they diverge significantly from stoichiometrically ideal values, making these identifications largely tentative. All values are given in atomic %.

| Wt.% | O | Na | Mg | Al | Si | P | S | K | Ca | Sc | Ti | V | Cr | Fe | Cu | Zr | Cd | Pb | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AT8039 | 41.8 | nd | 0.1 | 0.9 | 10.6 | nd | nd | nd | 0.3 | nd | 31.4 | nd | nd | 0.4 | 13.8 | nd | 0.2 | 0.5 | nd |
| | 45.4 | 0.5 | 1.1 | 18.6 | 22.9 | nd | nd | 9.4 | nd | nd | 0.5 | nd | nd | 1.3 | 0.3 | nd | nd | nd | nd |
| | 45.6 | nd | 0.1 | 12.5 | 11.4 | nd | 9.2 | 5.1 | 0.5 | nd | nd | nd | nd | 0.5 | 15 | nd | nd | nd | nd |
| | 36.1 | nd | 0.3 | 8.2 | 19.5 | nd | 5.7 | 3.3 | 0.7 | nd | nd | nd | nd | 0.9 | 24.1 | nd | nd | 1.4 | nd |
| | 28.3 | nd | nd | 0.4 | 2.8 | nd | nd | nd | 0.2 | nd | nd | nd | nd | 66.3 | 1.3 | nd | nd | 0.7 | nd |
| | 36.9 | nd | nd | 0.4 | 14.1 | nd | nd | nd | 0.4 | 0.5 | nd | nd | nd | 0.5 | nd | 45.4 | nd | nd | 2 |
| | 17.4 | nd | 0.3 | 0.9 | 2.4 | 1.8 | nd | nd | 3.7 | nd | nd | 9.4 | 0.4 | 0.8 | 13.2 | nd | nd | 49.8 | nd |
| | 28.9 | nd | 0.8 | 1.5 | 4.4 | 1.8 | nd | 0.3 | 3.9 | nd | nd | 7.7 | 0.5 | 1.2 | 11 | nd | nd | 38.1 | nd |
| **At. %** | **O** | **Na** | **Mg** | **Al** | **Si** | **P** | **S** | **K** | **Ca** | **Sc** | **Ti** | **V** | **Cr** | **Fe** | **Cu** | **Zr** | **Cd** | **Pb** | **U** |
| | 66.7 | nd | 0.2 | 0.9 | 9.6 | nd | nd | nd | 0.2 | nd | 16.7 | nd | nd | 0.2 | 5.5 | nd | 0.04 | 0.1 | nd |
| | 60.5 | 0.4 | 1 | 14.7 | 17.4 | nd | nd | 5.1 | nd | nd | 0.2 | nd | nd | 0.5 | 0.1 | nd | nd | nd | nd |
| | 64.7 | nd | 0.1 | 10.6 | 9.2 | nd | 6.6 | 3 | 0.3 | nd | nd | nd | nd | 0.2 | 5.4 | nd | nd | nd | nd |
| | 57.3 | nd | 0.3 | 7.7 | 17.6 | nd | 4.5 | 2.1 | 0.4 | nd | nd | nd | nd | 0.4 | 9.6 | nd | nd | 0.2 | nd |
| | 57.1 | nd | nd | 0.5 | 3.2 | nd | nd | nd | 0.2 | nd | nd | nd | nd | 38.3 | 0.6 | nd | nd | 0.1 | nd |
| | 68.7 | nd | nd | 0.4 | 14.9 | nd | nd | nd | 0.3 | 0.3 | nd | nd | nd | 0.3 | nd | 14.9 | nd | nd | 0.3 |
| | 53.8 | nd | 0.6 | 1.6 | 4.2 | 2.8 | nd | nd | 4.6 | nd | nd | 9.1 | 0.4 | 0.7 | 10.3 | nd | nd | 11.9 | nd |
| | 65.7 | nd | 1.2 | 2.1 | 5.7 | 2.1 | nd | 0.3 | 3.5 | nd | nd | 5.5 | 0.3 | 0.8 | 6.3 | nd | nd | 6.7 | nd |

Table 7-5 Selected point analyses from AT8039, an ore sample excavated in Area 4. Values in the upper portion of the table are in weight % while the corresponding values in atomic % are given in the lower half. Note, however, that in contrast to the gangue materials, this ore sample contains neither As nor Sb.

Despite several points where the data show modest ambiguities, the results for the compositional analysis of slags are clear. The smelting slags are suggestive of a fuel-efficient process that, when considered alongside the microscopic data, was capable of attaining temperatures on the higher end of the ancient range (1200-1350°C) (Bourgarit, 2019, p. 213). This is in line with finds of small shaft furnaces of 30-40cm in diameter with wall thicknesses on the order of 10cm in Areas 1 and 4. According to Rehder (2000, pp. 16, 23), these reported dimensions fall approximately at the point where both ambient heat loss and space velocity (air flow in meters per minute) necessary to maintain temperature begin to level off, likely representing the point where the impact of these factors could not be perceived without the aid of modern measuring equipment. Following Rehder's (2000, pp. 170–172) suggested space velocity of 5-15m/m for ancient furnaces, these parameters should have been adequate to achieve temperatures in the neighborhood of 1,400°C. Considering that the smelting slags from Tell

Atchana have been shown to have melting temperatures around 1,200°C, it is curious that larger slag cakes or indications of tapping have not been found, since the slag compositions and temperatures attainable would have facilitated either possibility. As mentioned in chapter 3, one possibility is that this material was periodically removed from the workshop area, in line with the frequent cleaning suggested by the archaeological evidence. Another option, however, is that despite the rather well-developed process parameters, the scale was kept small enough that large volumes of slag were never produced and/or the smelting process may have been kept short enough that there was not a large agglomeration of material at the bottom of the furnace to form the expected large fragments of slag. This explanation in keeping with the archaeological evidence (see also the discussion of Hittite texts in section 5.2), which for Area 4 suggests a modest multi-craft compound, while the limited evidence of pyrotechnical installations from Area 1 suggests similarly small-scale activity.

The crucible slags are typical of this type of material, exhibiting extreme heterogeneity and a substantial metal content. The high calcium content of these slags, beyond the range typically expected, is likely related to a combination of a high fuel-charge ratio as well as reaction between slag and the very calcareous clays of the Amuq Valley. As such, despite the lack of intact crucible fragments, their presence can be inferred to a certain extent. Finally, the observation that many of these slags contain prills of high-Sn metal and pure copper is indicative of active alloying processes. Given that these prills appear to lack the suite of accessory elements seen in some of our alloying material from chapter 6, this may indicate a separate alloying process involving the use of purer tin.

## 7.3 LA-ICP-MS Results

As mentioned above, due to the great heterogeneity of slags, laser ablation was not conducted on this set of material since the chance of attaining representative results is relatively low. This is, however, an area of potential future research as laser ablation approaches to high-sensitivity slag analyses would greatly simplify sample preparation procedures. In the following section, I will discuss the LA-ICP-MS results for the metal assemblage, as well as for several larger prills embedded in slags[1]. The data presented here have two primary uses. First, they serve as supporting provenance information for the lead isotope data to be presented in the next chapter. In particular, Ni/Ag abundance ratios are of importance as elements that are likely to remain relatively unchanged in the transformation from ore to metal, though the general pattern of trace elements is informative (Pernicka, 1999, 1987, pp. 630–642). Second, these data provide additional clues into the technological processes being employed with relevance to the question of local bronze production involving speiss. Because we have already investigated the major element compositions in the SEM-EDS data, focusing on refining processes and bronze types, tin and iron have been excluded from many of the following considerations, as has copper since it is the major component of all the samples.

Before delving into the sample data, the quality assurance data values are presented in Table 7-8. Here, we can see strong agreement internally between 8 different analyses of standard 36X SP1A run between 02-12-2020 and 02-28-2020. Further, the averaged values of these analyses are in generally close agreement with the published analytical values for the standard, with the standard deviation between the two rarely exceeding the published uncertainty. As such,

[1] There is a significant caveat here in as far as any single prill embedded in slag may vary significantly from other prills in the same slag.

the results presented here may be considered fully quantitative with the exceptions mentioned in section 7.1. Furthermore, given the heterogeneity of 36X SP1A, which exhibits significant compositional segregation at the microscopic level, the fact that these results have come in so close to published values should serve to bolster confidence in the use of laser ablation on heterogeneous materials (Dussubieux et al., 2008; Sarah and Gratuze, 2016).[2] Finally, in those cases where results are rendered uncertain due to the presence of intergranular

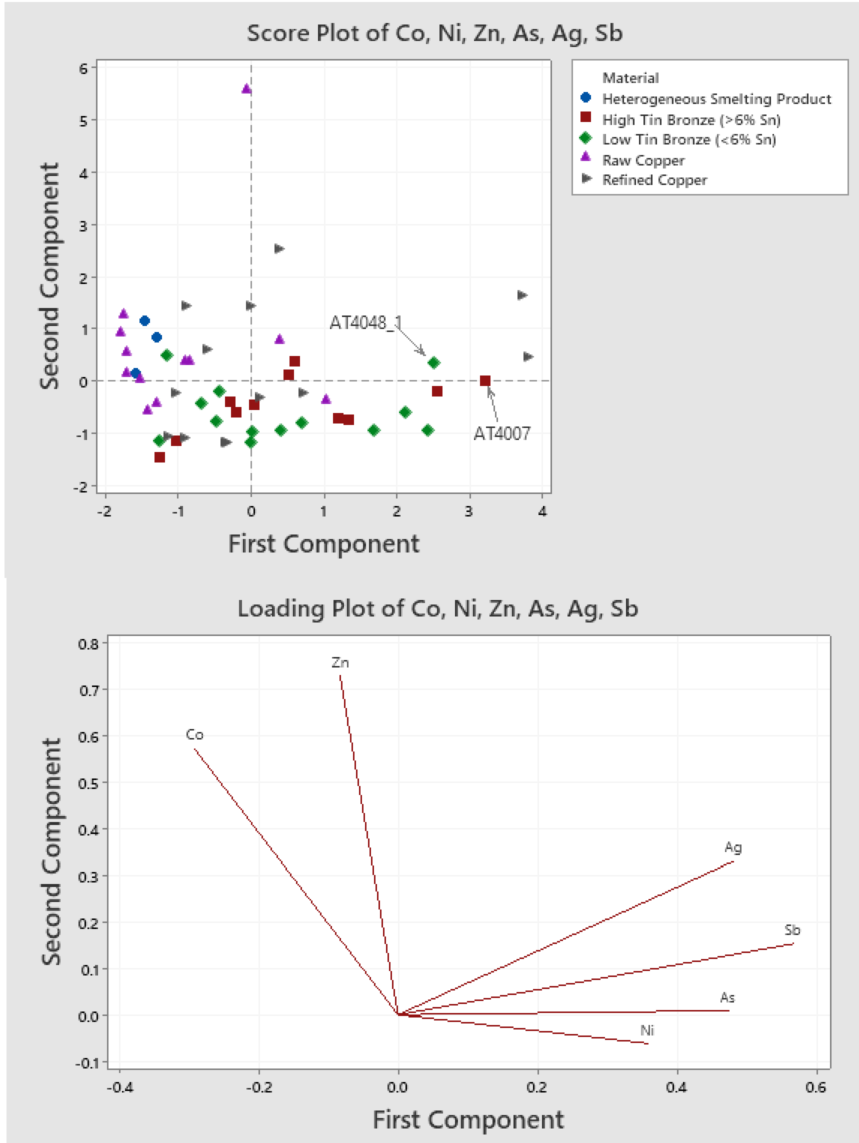



Figure 7-13: Score and loading plots for Co, Ni, Zn, As, Ag, and Sb. To improve readability, three significant outliers (AT8666, 21510, and 23799) were excluded. The extremely high Co and Ni contents of these three samples caused significant skewing of the results, reversing the direction of the Co and Ni loading lines.

[2] There is a caveat regarding elements such as lead and bismuth which segregate irregularly within a copper matrix, making their analysis via laser ablation difficult. As such, a larger degree of error should be expected with these, though the quality assurance data is quite consistent with lead. Regarding selenium and tellurium, their tendency to concentrate in sulfide phases of copper also means that a greater degree of error should be expected – since 36X SP1A was not certified for either element, it is difficult to suggest a relative degree of certainty for these.

corrosion or other defects, often observable in the time-resolved data (Sarah and Gratuze, 2016), they have been marked as such in the data presented in appendix 4.

Based on an initial principal component analysis involving those elements for which we have the most reliable values, and which tend to be more homogeneously distributed in a copper matrix, a distinct pattern emerges that shows two significant features (Figure 7-13). First, the overall clustering pattern is tight, with most dispersal occurring along positive relationships between Ni, As, Sb, and Ag associated with tin bronze. In addition, raw copper and HSP also cluster tightly together. Refined copper is more broadly dispersed, but still in proximity to the less processed varieties. This distribution can be explained by inconsistent element loss during refining or differing provenance. In the distribution of tin bronzes. a substantial number of these artifacts plot as an apparent extension of the raw and refined copper fields. Given the often low contribution of trace elements deriving from tin smelted from cassiterite (Berger et al., 2018, p. 77; Chirikure et al., 2010, pp. 1659–1660), this could be taken to suggest that these are made from alloying with pure tin metal or Sn-rich master alloy – tentatively associating then with the tin-bearing crucible slags. Further right on Figure 7-13, a dispersed tail of bronzes develops,

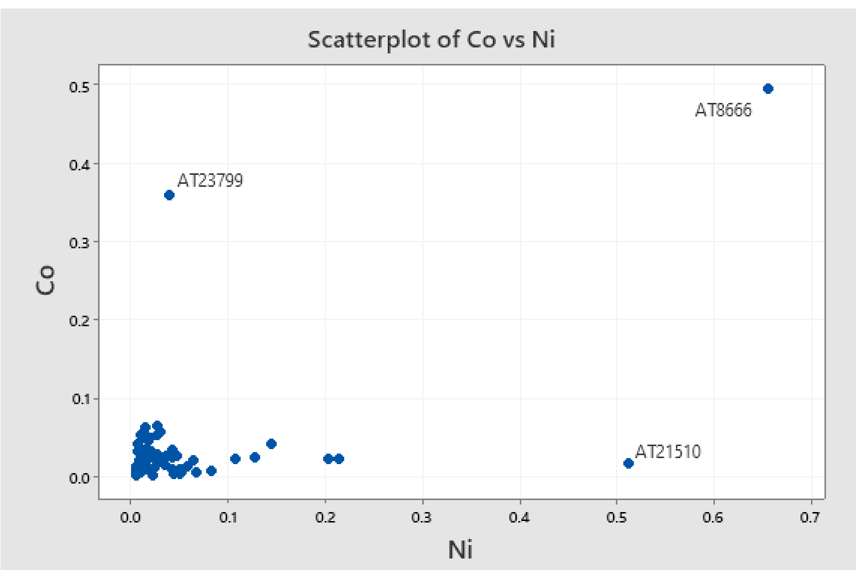



Figure 7-14: Scatterplot illustrating the relationship between Co and Ni in absolute values including the three outliers excluded from the PCA results. The majority of samples, clustered in the lower left corner, are relatively consistent in their Co-Ni with a potential slightly negative relationship, probably reflecting the greater tendency for Co to oxidize in copper melts.

characterized by elevated quantities of Ni, As, Sb, and Ag. I would suggest that these were produced either from direct smelting involving speiss as a byproduct, or through the addition of tin-bearing speiss. As indicated in the plot, AT4007 and AT4048_1, discussed in chapter 6 as prime examples of this activity, are prominent along this trend.

Several outliers not included in Figure 7-13 due to their unusual Co and Ni values (AT8666, 21510, and 23799) (Figure 7-14), pose significant challenges for interpretation. For AT23799, an HSP sample, the absolute values of cobalt and nickel are almost identical to those given for ore samples derived from Ergani Maden (Seeliger et al., 1985, p. 653). Taken against the Sb/As ratio (Sb/As = 0.004 for AT23799) for Ergani ores (Sb/As = 1-0.1) (Seeliger et al., 1985, p. 655), however, it is unlikely that this object was produced from the eastern Taurus deposits. AT8666, an object made from raw copper, represents a generally unusual sample, both in its exceptionally high Ni and Co contents, as well as its high tin values. I am currently unaware of any comparable material. Finally, AT21510, a low tin bronze, exhibits an unusually high Ni content with Co values in line with other samples. Indeed, it appears to represent a continuation of the small tail of samples extending along the X axis of Figure 7-14.

In pairwise comparisons of elements (Figure 7-15), a similar pattern begins to emerge where raw copper and HSP form a reasonably well-defined cluster and refined copper plots more diffusely, often overlapping with a portion of the bronzes. Based on the Ni-Ag plot in conjunction with Figure 7-13, raw and refined copper can largely be suggested to stem from a common source, while a tail of bronzes continuing a positive upward trend along the same line may suggest a related (or the same) geological deposit. In the Ni-Co plot the distinction is clearer, with a small cluster of bronzes situated to the upper-left of the main body of samples. Although a slight negative relationship appears to prevail here, which would be in line with

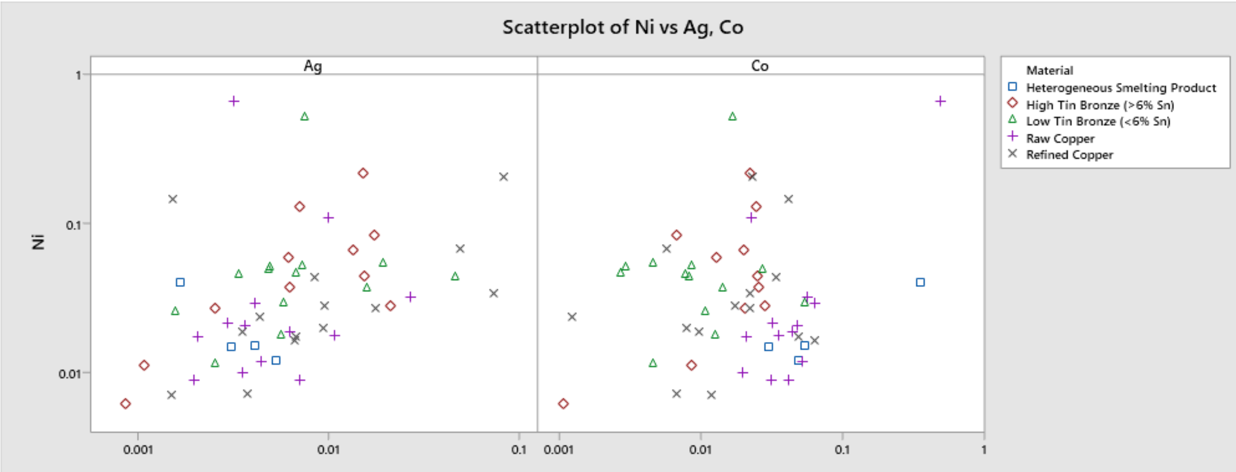



Figure 7-15: Scatterplot of Ni vs Ag and Ni vs Co presented in log-scale.

Sabatini (2016, pp. 90–91), the extent to which Co and Ni are lost during copper melting seems to be negligible based on experimental data (Pernicka, 1999, p. 165; but see, Merkel, 1982, p. 338). Minor Co loss is likely reflected in the very slight shift to the upper left of the refined copper field in this plot. By contrast, the bronze cluster to the upper left, as well as the various outliers, were likely produced from ores with rather different Co and Ni values. If we assume related geological deposits for the parent ores of this material based on the more continuous Ni vs. Ag data, then the Ni vs. Co plot would seem to provide a criterion for distinguishing within this group.

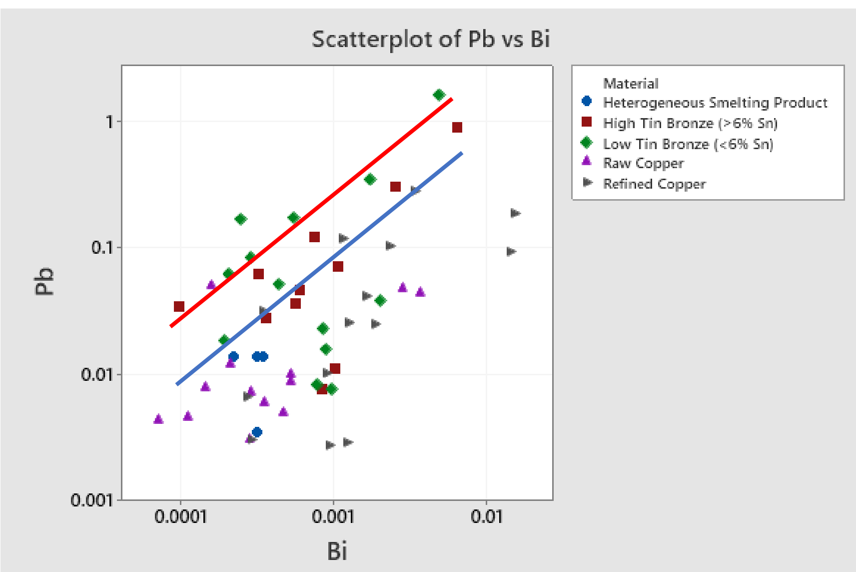



Figure 7-16: Pb vs. Bi scatterplot, data presented as wt.%. The red line defines the lower edge of the trend for bronzes likely to be speiss-related, while the blue line marks the upper edge of the trend defined by raw and refined copper. The material between the two lines does not fall securely in either group based on the data observed so far.

Although, the Pb vs Bi biplot (Figure 7-16) displays what at first

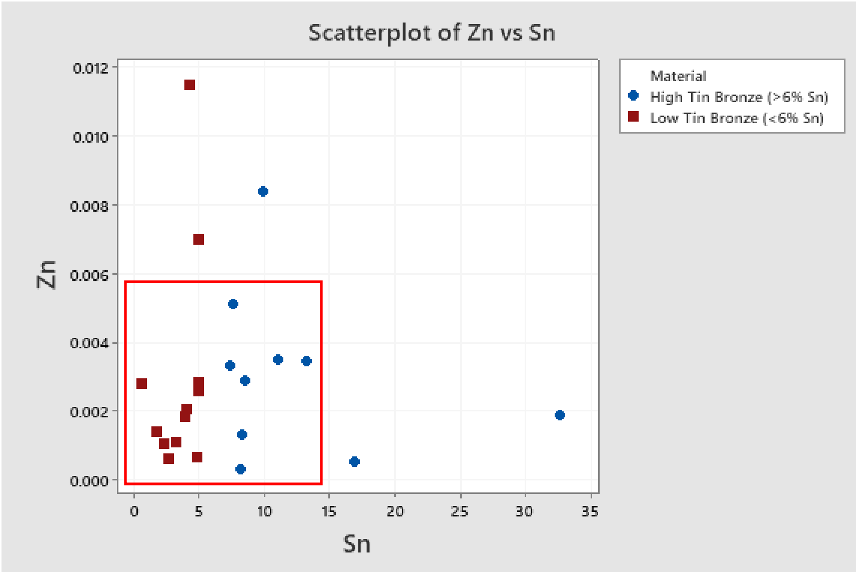



Figure 7-17: Zn vs. Sn scatterplot showing all bronze samples. The red box indicates the samples included in Figure 7-18.

appears to be a somewhat unruly distribution, the data does in fact coincide with what we have seen so far. The first point to note is the concentration of raw and refined copper along a trend (below the blue line) characterized by a relatively higher ratio of Bi to Pb, illustrated by its position further right on the plot. Interspersed with this group are a series of bronzes that were likely produced with tin or a master alloy mixed with local copper. The bronzes situated at and just above the blue line may have been produced using a locally made master-alloy, since they often – but not always – appear as part of a distinct cluster of bronzes (Figure 7-16). The bronzes on and above the red line are those that have frequently been referred to above as potentially speiss related.

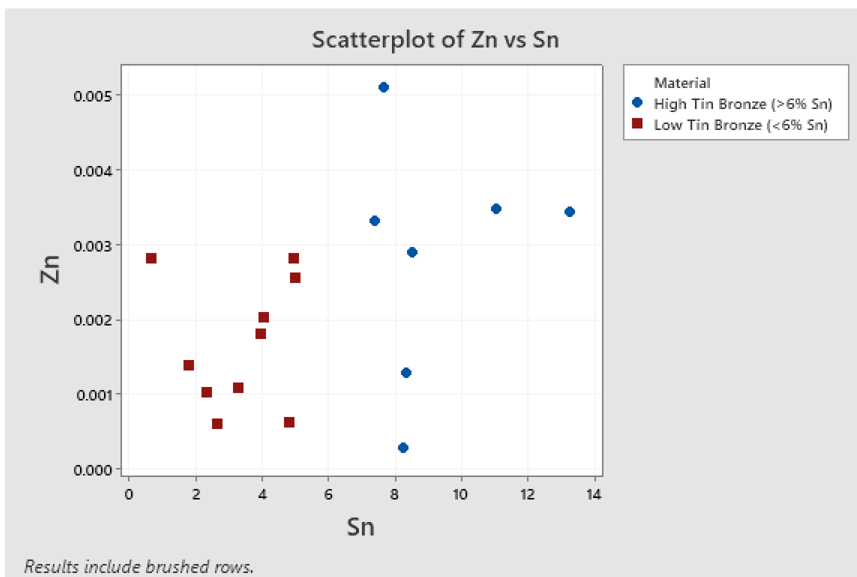



Figure 7-18: Zn vs. Sn scatterplot showing the samples highlighted in Figure 7-17.

Thus far, the evidence has strongly suggested an association of tin with a variety of elements known to occur together in the polymetallic copper ores that characterize the Taurid deposits (Akinci, 2009; Çağatay et al., 1991; Özbal et al., 2002), though I have avoided any specific comment on potential tin sources up to now. The issue of tin in Anatolia and its use has been a contentious subject in archaeology for several decades and it is unlikely to be resolved here (Berger et al., 2019; Muhly, 1993, 1985; Yener et al., 2015; Yener and Özbal, 1987; Yener and Vandiver, 1993, p. 19). Nevertheless, the previously discussed speiss samples and the relationship of elements such as As, Sb, Ni, and Ag in the present dataset taken alongside the known presence of stannite deposits in co-occurrence with fahlerz, sphalerite, and other sulfosalts at locations in the Taurus such as Bolkardağ is particularly fortuitous in light of the Zn and Sn values for the bronze assemblage (Çağatay and Arman, 1989; Wagner et al., 1989, p. 674; Yener and Özbal, 1987). In particular, as the biplot for Zn vs. Sn (Figure 7-17) shows, there is a reasonable correlation which, when adjusted for outliers (Figure 7-18), becomes more marked. This may be taken as a preliminary indication for the potential use of stannite in bronze production, with the minor Taurid deposits being the only regionally attested occurrence so far

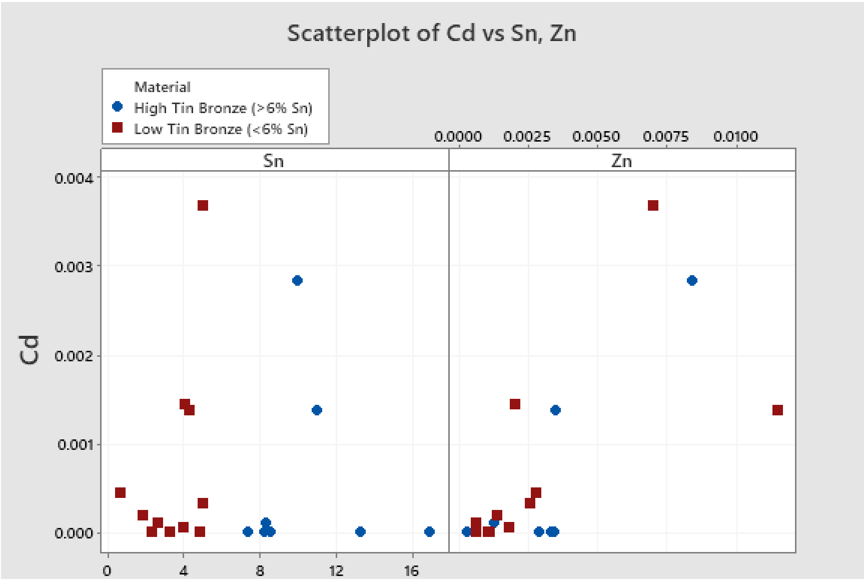



Figure 7-19: Dual scatterplot displaying Cd vs. Sn and Cd vs. Zn. The higher-Cd points include both AT4007 and 4048_1, which have been mentioned repeatedly as examples of speiss-related bronze stemming from an early stage in the production process.

| | 8491_1 | 8491_3 |
|---|---|---|
| Mg | 0.0005 | 0.0002 |
| Al | 0.0079 | 0.0017 |
| P | 0.009 | 0.004 |
| Cr | 0.0005 | 0.0002 |
| Mn | 0.001 | 0 |
| Fe | 0.0155 | 0.0078 |
| Co | 0.0109 | 0.0002 |
| Ni | 0.1043 | 0.0019 |
| Cu | 60.05 | 99.9 |
| Zn | 0.0021 | 0.0001 |
| As | 2.7584 | 0.056 |
| Se | 0.0084 | 0.0044 |
| Ag | 0.0141 | 0.0062 |
| Cd | 0 | 0 |
| Sn | 36.82 | 0 |
| Sb | 0.1483 | 0.0103 |
| Te | 0.0023 | 0.0015 |
| Pb | 0.0466 | 0.0027 |
| Bi | 0.0007 | 0.0004 |

Table 7-6: Trace element data for two prills from crucible slag AT8491. Note, in particular, the comparative values for Pb, Sb, Ag, As, Zn, Ni, and Co in reference to the discussion on speiss and speiss-related bronzes. Because this is two prills in a single sample, the importance of this data should not be overstated, but in light of the supporting evidence the association of these elements with a high-Sn value is striking.

(Çağatay and Arman, 1989; Muhly, 1985, p. 276), though Wagner et al. (1989, p. 674) came out against this possibility. Within this general group, there appears to be a further subset defined by elevated levels of cadmium[3] in a loosely defined positive relationship with both tin and zinc (Figure 7-19). At present, there is insufficient data on Cd in archaeological assemblages due to a general lack of testing for this element to properly contextualize this data from an archaeological perspective. Nevertheless, this data does suggest a link between Cd, Sn, and Zn, which may argue for presence of the mineral Černyite (Kissin et al., 1978) as part of the ore charge in some instances. At the very least, it suggests a novel origin for a subset of the tin, given that the presence of Cd above the ppm level in the metal presupposes its significant presence in the ore based on its extreme volatility (Bodsworth, 2018, p. 42). Though further analysis is necessary, laser ablation results (Table 7-6) from two prills entrapped in a crucible slag may be enlightening, suggesting the suite of elements associated with local bronze production processes, which are in good agreement with the discussion so far.

[3] Crustal abundance = 0.15ppm

## 7.4 Discussion

In the previous discussion, three main points have been emphasized. The first of these is that the SEM-EDS data for the metals strongly supports the categorizations (Low-Sn Bronze, High-Sn Bronze, Raw Copper, Refined Copper) developed during optical microscopic analysis. The primary addition that the SEM-EDS results made to this discussion was to allow for the definition of high and low-tin bronze groups, as well as identifying subtle patterns within these groups and the homogenizing impact of refining activity on the general composition of the metal assemblage. When viewed chronologically, this data has shown a period of significant technological consistency at the site, followed by its potential collapse or reorganization – seemingly in concert with a major political shift in the region, the direct assumption of control by the Hittite Empire.

The second point is that the SEM-EDS data for the slags generally supports the discussion in chapter 6, albeit with a certain level of ambiguity. This is not unexpected since crucible slags are known for extreme heterogeneity, meaning that they can only point to particular practices, but never exclude them (Rademakers and Rehren, 2015). In this respect, this dataset has helped to bolster the discussion of technological practices at the site, pointing to the substantial presence of direct-alloying to produce tin-bronze. Perhaps more interesting, however, is the identification of smelting slags with their major copper component present as primary sulfides, supporting the interpretation that they are the result of local exploitation of sulfide ores. This point is further bolstered by the trace element data that indicates similar geological settings for the ores used to produce these metals. That smelting was taking place in the site is supported by accompanying subsidiary analyses of gangue minerals, ore inclusions in such minerals, and a single example of ore. The observation of high CaO contents in the slags and analysis of a limited amount of adhered crucible material and its associated major oxides has also allowed us to suggest clay sources for the production of technical ceramics which are, unsurprisingly, local.

| AT Number | Pb vs. Bi | Sn vs. As | Ni vs. Co | Ni vs. Ag | Sn vs. Zn | PCA |
|---|---|---|---|---|---|---|
| AT569 | Y | Y | Y | P | High-Sn Outlier | Y |
| AT4007 | Y | Y | Y | Y | Y | Y |
| AT4048_1 | Y | Y | Y | Y | High-Zn Outlier | Y |
| AT4101 | Y | Y | Y | Y | Y | Y |
| AT4309 | Y | N | Y | Y | Y | Y |
| AT7288 | Y | N | N | P | Y | Y |
| AT8499 | Y | N | Y | Y | Y | Y |
| AT20433 | Y | Y | N | P | N | Y |
| AT21454 | Y | Y | Y | Y | Y | Y |
| AT21510 | Y | N | N | P | Y | Y |

Table 7-7: Table displaying those samples that repeatedly appear as candidates for speiss-related bronze production. Column headings list the plot under consideration with a simple Y (yes), N (no), P (possibly) indicating whether the sample appeared as part of the group in that plot. Possibly refers to instances where a sample appeared at the edge of a group or between groups, making inclusion/exclusion questionable. While there are a number of other candidates, any sample that received three "No's" was excluded from the list.

Finally, the trace element data has been instrumental in providing a firm foundation for the discussion of multiple bronze production methods in practice at the site, indicating candidate samples for which bronzes may have been produced via direct alloying with more-or-less pure tin or master-alloy as opposed to the previously discussed speiss-related methods. The consistent Zn-Sn relationship suggests that, regardless of which method was used, some of the tin may have been produced from stannite. Furthermore, the results of principal component analysis have been unambiguous. While one segment of the bronzes shows close elemental associations with the raw and refined copper groups, another displays enrichment in elements closely associated with speiss samples excavated at Tell Atchana, including two samples of "in-process" metal. For the raw and refined copper, these two groups plot closely together enough that I may suggest a common geological source for this material, though this will be tested in the next chapter with lead isotope data. The copper utilized in the bronzes associated with these groups likely originated from the same or a similar source. The tin used in their production, if a common tin-source is assumed, would likely be a master-alloy derived from local smelting practice. Decreased quantities of trace elements compared to potentially direct-smelted bronzes would be due to dilution in copper and loss to oxidation and volatilization. A small subset of samples from each category falls well outside the general group – these are likely to be either imported metals, and/or their material was sourced from different deposits.

Within the broader aims of this research, these results continue to work against my starting hypothesis that metal industries should be more integrated and centralized relative to the palace and its connections to trade in the eastern Mediterranean. The self-contained nature of the metallurgical industry presented thus far has proven wholly unexpected and serves to challenge existing narratives of east Mediterranean connectivity, supporting more localized technological systems. Though it may seem counterintuitive at first glance, this is arguably supported by the variety of apparent material sources in play. Long-distance connectivity is often based on bulk shipment and processes (mixing and recycling) that lead to homogenization. These are not well-represented in this assemblage. Finally, the possibility that Taurid tin may have been in use shows the continued importance of locally focused networks.

| | 36XSP1A 02-12 | 36XSP1A 02-14 Run 1 | 36XSP1A 02-14 Run 2 | 36XSP1A 02-14 Run 3 | 36XSP1A 02-15 Run 1 | 36XSP1A 02-15 Run 2 | 36XSP1A 02-28 Run1 | 36XSP1A 02-28 Run2 | Average | Standard Deviation | 36XSP1 Certified Value | % Error - Certified Value vs. Analytical Average | Certified Value Uncertainty |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $^{24}Mg$ | 0.0096 | 0.0094 | 0.0021 | 0.0042 | 0.007 | 0.0206 | 0.005 | 0.0014 | 0.0074 | 0.0033 | 0 | N/A | - |
| $^{27}Al$ | 0.0062 | 0.0037 | 0.0042 | 0.0023 | 0.0024 | 0.003 | 0.0057 | 0.0034 | 0.0039 | 0.0009 | 0.002 | 94% | 0.0001 |
| $^{31}P$ | 0.004 | 0.004 | 0.004 | 0.003 | 0.003 | 0.005 | 0.004 | 0.004 | 0.004 | 0.0007 | 0.003 | 35% | - |
| $^{52}Cr$ | 0.0048 | 0.006 | 0.0105 | 0.0028 | 0.0023 | 0.0027 | 0.0026 | 0.0027 | 0.0043 | 0.0021 | - | N/A | - |
| $^{55}Mn$ | 0.0826 | 0.0837 | 0.0856 | 0.0847 | 0.0822 | 0.0851 | 0.0853 | 0.0898 | 0.0849 | 0.0026 | 0.084 | 1% | 0.005 |
| $^{57}Fe$ | 0.435 | 0.456 | 0.458 | 0.444 | 0.463 | 0.464 | 0.444 | 0.456 | 0.452 | 0.0105 | 0.45 | 1% | 0.02 |
| $^{59}Co$ | 0.0575 | 0.0504 | 0.0552 | 0.0565 | 0.0599 | 0.0525 | 0.0603 | 0.0542 | 0.0558 | 0.0032 | 0.057 | 2% | 0.002 |
| $^{60}Ni$ | 8.376 | 8.319 | 8.303 | 8.315 | 8.368 | 8.331 | 8.349 | 8.288 | 8.331 | 0.0428 | 8.33 | 0.01% | 0.08 |
| $^{63}Cu$ | 84.87 | 84.95 | 84.97 | 84.98 | 84.94 | 84.94 | 84.88 | 85.13 | 84.96 | 0.0176 | 84.9 | 0.07% | 0.15 |
| $^{66}Zn$ | 0.3425 | 0.3275 | 0.3485 | 0.3488 | 0.3468 | 0.3392 | 0.3356 | 0.2098 | 0.3248 | 0.0068 | 0.344 | 6% | 0.008 |
| $^{75}As$ | 0.0009 | 0.0022 | 0.0022 | 0.0024 | 0.0024 | 0.001 | 0.0021 | 0.0012 | 0.0018 | 0.0006 | - | N/A | - |
| $^{82}Se$ | 0.0032 | 0.0029 | 0.0013 | 0.0036 | 0.0031 | 0.003 | 0.0016 | 0.0023 | 0.0026 | 0.0005 | - | N/A | - |
| $^{107}Ag$ | 0.00483 | 0.00496 | 0.00547 | 0.00471 | 0.00427 | 0.00436 | 0.004 | 0.00438 | 0.00462 | 0.0004 | 0.005 | 8% | 0.001 |
| $^{114}Cd$ | 0 | 0 | 0 | 0 | 0.0001 | 0 | 0 | 0 | 0 | 0.0079 | - | N/A | - |
| $^{120}Sn$ | 5.771 | 5.744 | 5.711 | 5.715 | 5.688 | 5.72 | 5.791 | 5.727 | 5.733 | 0.0554 | 5.75 | 0.29% | 0.05 |
| $^{121}Sb$ | 0.01682 | 0.01622 | 0.0179 | 0.01683 | 0.01482 | 0.01722 | 0.01748 | 0.01325 | 0.0163 | 0.002 | 0.0177 | 8% | 0.0014 |
| $^{125}Te$ | 0.0002 | 0.0001 | 0.0001 | 0.0009 | 0.0007 | 0.0003 | 0.0004 | 0.0004 | 0.0004 | 0.0002 | - | N/A | - |
| $^{208}Pb$ | 0.012 | 0.0113 | 0.0124 | 0.0123 | 0.0117 | 0.0112 | 0.0111 | 0.0117 | 0.0117 | 0.001 | 0.0115 | 2% | 0.0016 |
| $^{209}Bi$ | 0.0013 | 0.0032 | 0.0046 | 0.003 | 0.0015 | 0.0013 | 0.0031 | 0.003 | 0.0026 | 0.0014 | 0.0039 | 33% | 0.0005 |
| | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | | 99.96 | | |

Table 7-8: Quality assurance values for MBH 36XSP1A in wt.%.

# 8 Lead Isotope Analyses

Originally developed in the geosciences as a method for determining the age of geological formations, lead isotope analyses gained prominence in Near Eastern archaeology with the initiation of several large analytical projects during the 1980's and 90's (Gale and Stos-Gale, 1986, 1982; Sayre et al., 2001; Wagner et al., 1986; Yener et al., 1991, 1990). The primary impetus for these programs was a realization that trace element compositions alone were insufficient for the task of determining the provenance of ores used in the manufacture of ancient metals due to significant variation within ore bodies as well as element loss and enrichment due to oxidation and volatilization during pyrometallurgical processes. Lead isotope analyses, based on comparing the ratios of $^{204}Pb$, $^{206}Pb$, $^{207}Pb$, and $^{208}Pb$ provided a solution to this problem.

The heart of this method lies in the comparison of non-radiogenic lead ($^{204}Pb$) to its radiogenic isotopes formed by the decay of $^{238}U$ ($^{206}Pb$), $^{235}U$ ($^{207}Pb$), and $^{232}Th$ ($^{208}Pb$). Because the isotopic composition of "primordial" lead from the formation of the planets in the solar system is known from iron sulfide (troilite) phases in meteorites[1], and because the precise decay constants of the parent isotopes of radiogenic lead are known, the accumulation of radiogenic lead versus non-radiogenic lead is time-dependent in a predictable manner. The use of this characteristic in geochronology is then based on the assumption that the earth's core acts as a reservoir containing Pb, U, and Th, with a constantly evolving composition based on this predictable radioactive decay. When core material is separated from this reservoir and becomes part of the earth's crust, crystallization processes and other mechanisms related to the formation

[1] This is based on the fact that these phases do not incorporate U or Th, therefore preventing changes in isotopic composition over time through the decay of their isotopes to lead.

of minerals typically exclude U and Th from these systems. Based on the known evolution of lead isotope values in the core derived from the decay constants of U and Th, the isotopic composition of a given geological sample can then be used to calculate the time when its incorporated lead was separated from the reservoir at the core. As such, geological features that formed at different times have different isotopic ratios.[2] Because these ratios remain relatively consistent[3] throughout ore bodies regardless of lead content, except for in situations where secondary mineralization has occurred or where U and Th have been included in the deposit, they provide a more reliable method for "fingerprinting" deposits than geochemical characteristics, which can vary based on formation processes of mineral assemblages as well as due to weathering processes.

| Region | Citations for Lead Isotope Data |
|---|---|
| **Cyprus** | (Gale and Stos-Gale, 2020, 1986, 1982; Stos-Gale et al., 1997; Webb et al., 2006) |
| **Turkey** | (Kuruçayırlı, 2015; Lehner, 2015; Sayre et al., 2001; Seeliger et al., 1985; Wagner et al., 1989, 1986; Yener et al., 1991, 1990) |
| **Aegean** | (Gale and Stos-Gale, 2020) – Oxalid Database |

Table 8-1: Citations for Lead Isotope data.

Given the level of specificity that these methods afford, they were seen as an ideal tool for use in archaeological efforts to link ore sources to metals produced in antiquity. The relationship has not always been smooth, however; after Stos-Gale et al. (1997) famously[4] hypothesized that all of the copper oxhide ingots produced in the 14$^{th}$ century BC and later originated from the Apliki ore deposit in Cyprus, many Near Eastern and Aegean archaeologists

[2] This explanation is a general overview of the idea behind lead isotopy, for a more thorough and technical discussion, see; (Faure and Mensing, 2005, pp. 261–268).
[3] There are, naturally exceptions to this that may originate from volcanic or metamorphic events, resulting in short-range variations in isotopic composition.
[4] Famous because of the debate it engendered. In light of current evidence, there is little to suggest the Gales' hypothesis was incorrect, and many archaeologists have since come to accept it.

began to doubt the efficacy of the method (Gale and Stos-Gale, 2012, pp. 73–74; Kassianidou, 2009, p. 63; Muhly, 2009, p. 29). The most extreme of these criticisms stemmed from Budd et al. (1995), who took the position that the pool of metals circulating in the Mediterranean during the Bronze Age was so thoroughly mixed that a single source hypothesis for oxhide ingots could no longer be maintained. Although the interpretation presented may have been overly extreme, the oxhide ingot data not showing the homogenization that would generally be expected from such a situation (cf. Nørgaard et al., 2019), this work did draw attention to the need for careful consideration of analytical data in light of archaeological context. Though it significantly damaged the reputation of LIA for archaeological purposes among non-specialists, since the initial furor surrounding this debate subsided the method has become well respected in archaeometric circles with more productive efforts being directed toward refining its use in archaeology (Albarède et al., 2012; Baron et al., 2014; Hauptmann, 2009; Pollard and Bray, 2015).

Because LIA has is usually used in the reconstruction of interregional trade networks, there is a tendency to classify the data at the level of site assemblages. Analyses are not differentiated based on artifact type or specific intra-site provenance. Part of the reason for this is the reasonable assumption that metal procurement operated at the site level, meaning that material from different sources would be evenly distributed within an assemblage. As such, LIA has been conceived of as a tool for macro scale analysis of inter-site exchange where each site represented a homogeneous aggregate. Further, as Budd et al. (1995, p. 26) indicated, it is often not useful to make analyses at the level of the individual mining site since

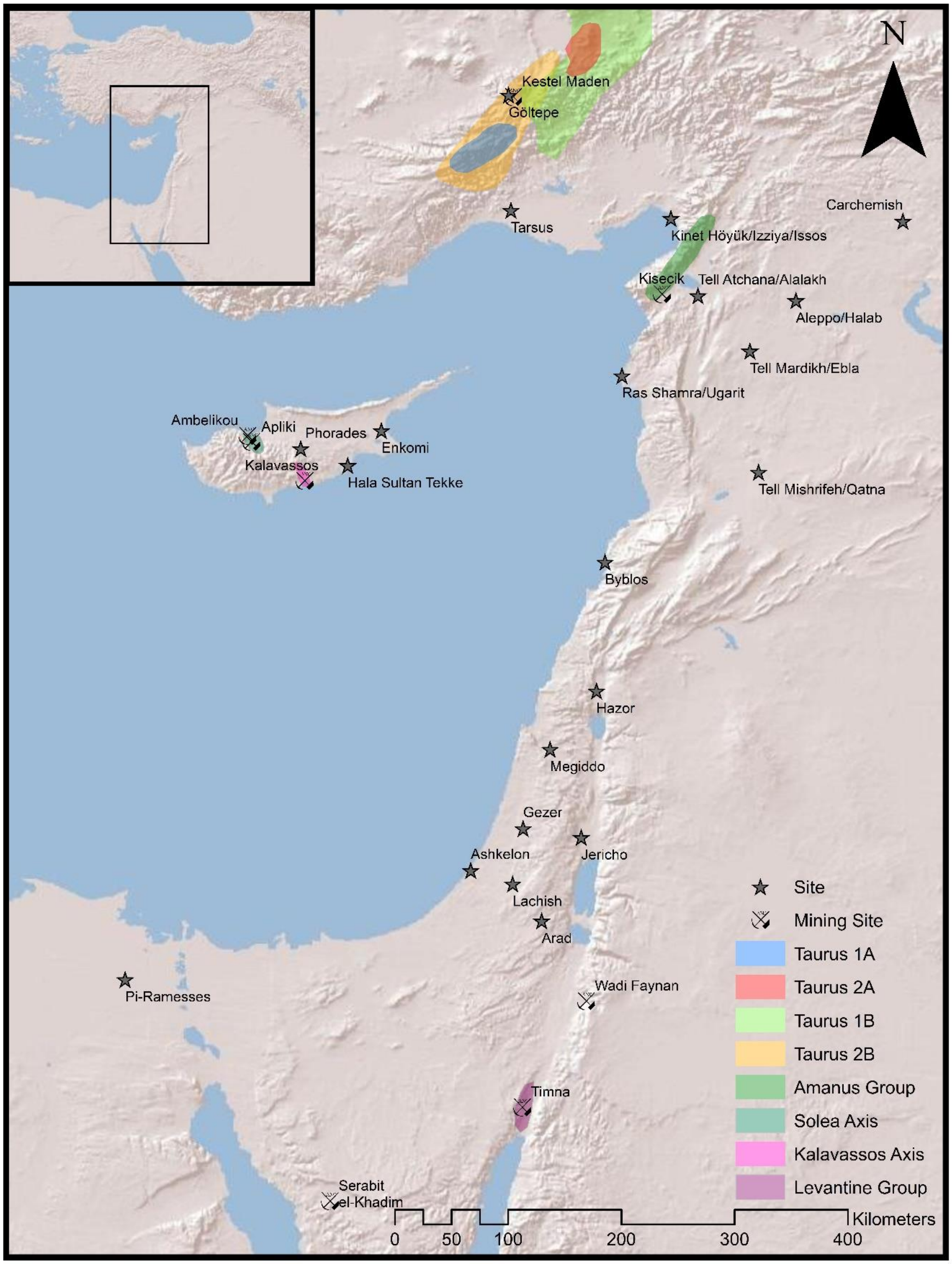



Figure 8-1: Map showing major sites mentioned in the text, a selection of 2nd millennium BC urban centers, known mining sites in the study area, and general indicators for the geographic extent of LI groups mentioned in the text. Markers for the LI groups are not comprehensive and should not be understood as definitive, they are merely a general guide. Group areas are based on locations samples were collected from, citations for this information are in Table 8-1.

any number of mines could have similar isotope ratios, while archaeologically, drawing links to single sites is not conducive to making generalizations.

This is a perspective that has been reinforced to a significant degree by our interpretation of the textual data originating from major sites in the Near East. With their focus on the management of state-industries, we have often extrapolated these systems of organization across the Near East and taken for granted that they were representative of the sites these texts originated from as a whole. Meanwhile, the focus on large-scale localized examples such as Cyprus or the southern Levant as paradigmatic has reinforced this view and led to the conclusion that Late Bronze Age metal industries acquired their raw materials through networks tied to a limited number of source areas.

As will be seen in the data from Tell Atchana, some of these positions require re-evaluation. First and foremost, though there is a minor amount of material that might be attributable to Cyprus and the Levant, the vast majority is Taurid in origin with a focus on the south-central Taurus and Bolkardağ. Second, at an intra-site scale of analysis, two assemblages are discernible linked to the Area 4 workshop and the Palace and Temple Annex. These are clearly differentiated networks with only limited overlap, meaning that there are two different models of procurement operating in parallel to supply to separate production units. It can no longer be assumed that site assemblages are homogeneous, nor can it be assumed that textual records speak for the organization of an entire site. This may be taken as support for the argument that state control of metal resources varied positively with distance from highland source zones. As procurement networks became less direct and more trade-mediated, states could exercise greater levels of control, while in situations where people could access such resources with limited oversight, they circumvented administrative mechanisms. This may be the reason for the variation seen between the cases of the Hittites, Ebla, and Alalakh seen in chapter 5. Finally, the LI data lends strong support to the evidence presented thus far for a unique technological style centered on the production of bronze in a speiss-related process. The dual character of the Alalakh assemblage and the specificity of this final aspect of its associated technological style suggest that the Area 4 workshop had a special association with the highland regions of the south-central Taurus, while the palace industry relied on a broader range of sources for raw material. Based on the considerations surrounding metallurgical communities in chapter 4, the general foundations of technological style and systems thinking, as well as the fusion of archaeological and analytical data presented in the next chapter, this may be taken to suggest that the occupants of Area 4 were specialists in the working of montane resources and likely either maintained links to highland populations from whom they acquired resources, or themselves were able to acquire these materials.

## 8.1 Methods

Lead isotope determinations for the present study were made using a Nu Plasma MC-ICP-MS in the University of Illinois Urbana-Champaign geology department. In addition, the below discussion will include Atchana LI data published in Johnson et al. (2020), as well as material analyzed by Lehner, Walton, and Kuruçayırlı. In addition to artifacts from Tell Atchana, the data here also include previously unanalyzed ore samples from Hassa and Kisecik in the Amanus Mountains and a single fragment of copper ore from the surface of Kestel Maden collected by Prof. K. Aslıhan Yener during her metallurgical surveys in the Taurus.

During initial sampling for this study, subsamples were taken from most objects prior to mounting in epoxy resin. These were then cleaned in a sonicator containing distilled water and subsequently mechanically cleaned with a stainless-steel dental pick to remove soil and other accretions. For samples that had not been subsampled during initial sampling, approximately 10mg of material was drilled from the epoxy-mounted sample using a hand drill and tungsten-steel bit. Most samples ranged between 10-50mg. Samples were then dissolved in 40µl twice distilled $HNO_3$ and left to evaporate overnight on a hot plate. They were then brought up in 0.5ml 0.5N HBr.

For column separation of lead, Bio-Rad© AG 1-X8 anion exchange resin was loaded into 1.5ml Teflon columns. Following two full rinses using 6N HCl and Milli-Q ultrapure water, columns were equilibrated using 8 drops 0.5N HBr. Samples were then charged into the columns, followed by a dropwise rinse of 75µl 0.5N HBr and two bulk rinses of 1ml 0.5HBr. Final elution of lead into 4ml tubes was made with two rinses of 10.5N HCl. Afterwards, samples were allowed to dry down overnight again. Finally, the samples were brought up in 40µl and diluted with 1.96ml Milli-Q ultrapure water.

Solution concentrations were determined through a simple CPS comparison against Bi values in an internal standard using a Thermo Scientific iCAP quadrupole ICP-MS. Aliquots were then taken from the parent solution of each sample and diluted to approximately 15ppb for analysis and spiked to 5ppb Tl for mass bias correction. A handful of samples did not contain enough lead for reliable evaluation. During analysis, total procedural blank was determined as 400pg with no correction being applied to the data. To evaluate instrument stability SRM 981 was run every 6 samples (appendix 5), also providing a correction factor for instrument-specific systematic offset. Through correction according to SRM 981 values provided by Todt et al. (2013), minor inconsistencies between labs and instruments (Baker et al., 2006) can be reasonably accounted for. The original parent solutions for all data presented here are to be archived at Mustafa Kemal University, Hatay, Turkey.

## 8.2 General Provenance

In line with the initial conclusions presented in Johnson et al. (2020), the majority of metals from Tell Atchana show association with ores from the south-central Taurus, with a particular emphasis on the mining district of Bolkardağ (Taurus 1A and parts of 2B). Starting at the coarsest level of analysis (Figure 8-2) including all of the samples from Tell Atchana, it can be seen that there are three sets of samples distinct from the main body. Two points fall within the area of Levantine (Timna) ores, although one of these overlaps completely with a single point from Bakır Dağ located just to the north of the Aladağ range. For the point in the most extreme upper-right corner, no potential source has been identified thus far. The group of four Amanus points above the main body of samples are all new ore analyses that help to characterize what is turning out to be an exceptionally complex ore body in terms of its lead isotope composition. Of the three Alalakh points that fall inside this group, two are ore samples - one from Area 4 and one from Area 1. At the lower-left end of the main cluster, a small tail of Atchana samples can also be seen in proximity to both Keban and a separate set of Amanus ores from Kisecik, though these do not overlap.

Looking more closely at the primary cluster of points, the emphasis on Taurid ores from groups 1A and 2B becomes more apparent, with the grouping at the lower left being rounded out by points from Taurus Other, originating primarily from the northern Aladağ. Based solely on LIA determinations, the somewhat diffuse cluster in the middle could reasonably be considered as recycled material. However, the presence of a raw copper sample in this group complicates that suggestion. There is a handful of samples associated with Taurus 1B and 2A, while another cluster in the upper-right of the main group overlaps partially with the tip of the Cypriot field (Solea axis).

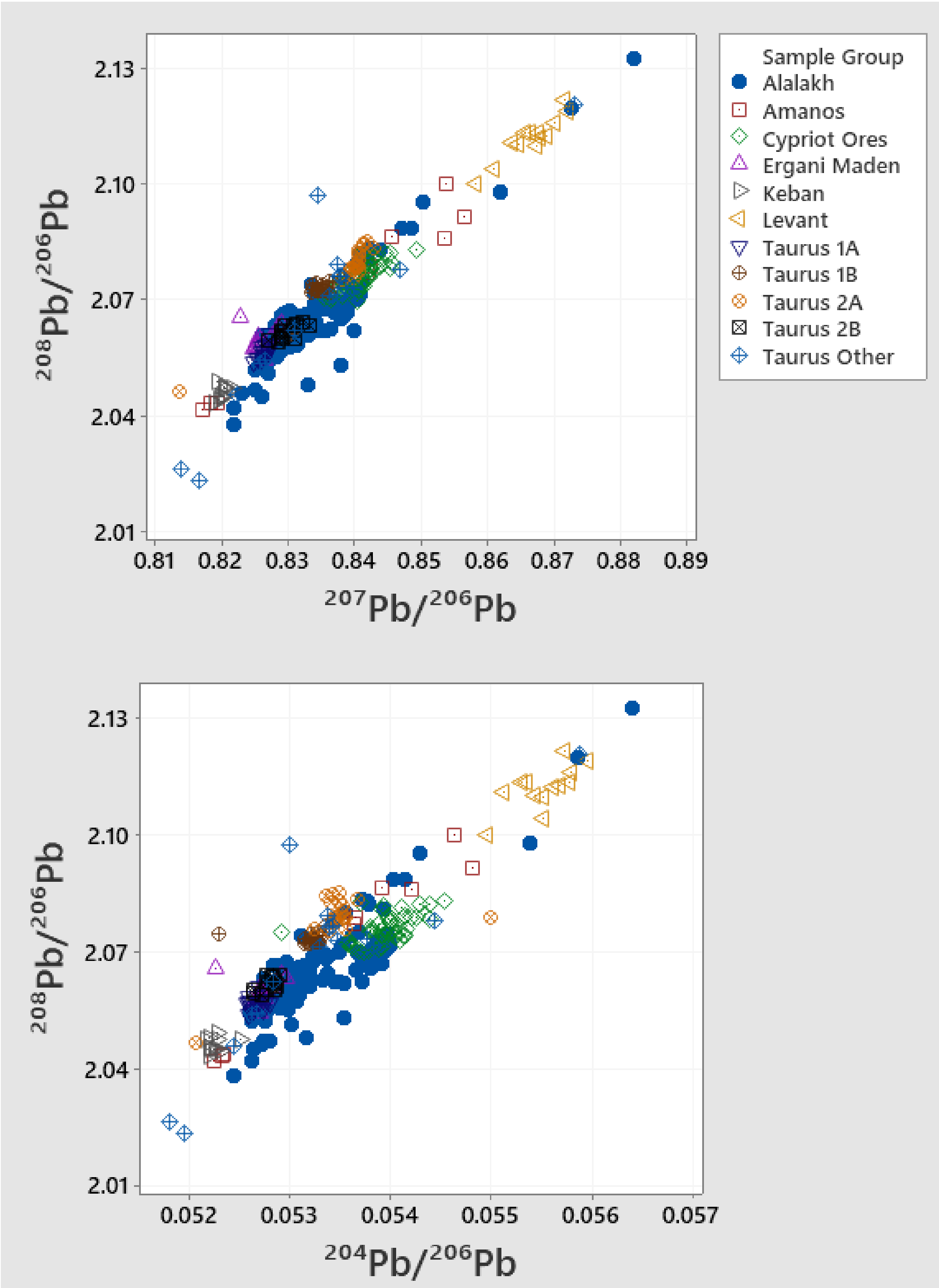



Figure 8-2: Summary plot of lead isotope values for all Tell Atchana LI analyses, in addition to values for ores from the Taurus, Ergani Maden, Keban, Cyprus, and the Levant.

There are two scenarios that explain the configuration of this last region. One is that the denser cluster that occupies the tip of the Cypriot field is unmixed metal from Cyprus, while the diffuse tail extending to the lower left is metal mixed with small amounts of southern Taurid material. Another is that this material is associated with the 'Taurus Other' point that more closely matches this cluster in both plots – with the diffuse tail still being mixed with other Taurid material. Finally, given the broad spread of Amanus signatures, this material could be the result of smelting ores from either extreme in the same process, with a single hypothetical point based on the average values of these ores partially overlapping with this cluster (Figure 8-3). At the very least, this hypothetical point can be used to argue that the unattributed points running through the middle of the main body are a result of this process. Mixing with the Taurus 1A ores in either of these latter cases would explain the lateral extension of this lower cluster to the left and right in Figure 8-3 (red line).

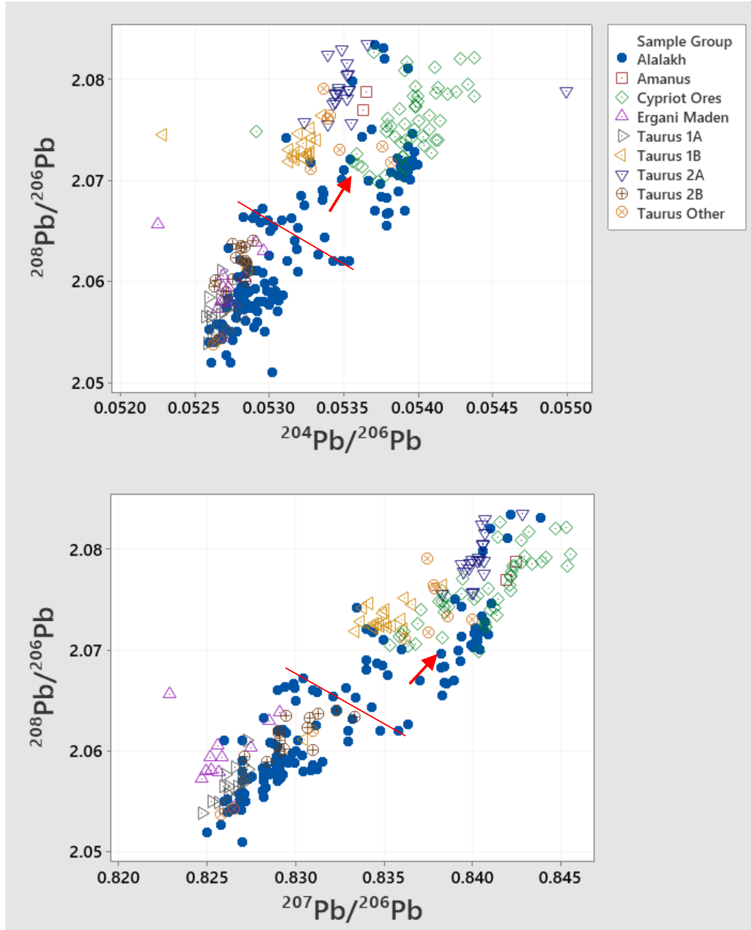



Figure 8-3: Plot showing only the data from the main cluster of points in Figure 8-2. The average point for the available Amanus ores is indicated by the red arrow in each plot. The red line indicates a hypothetical mixing front of the material from the upper and lower halves of the plot.

One final option for disambiguating these patterns lies in the use of a $^{204}$Pb-denominated plot for uranogenic $^{206}$Pb and $^{207}$Pb (Albarède et al., 2020, 2012; Artioli et al., 2020; Killick et al., 2020). This type of representation is the primary plot type used in geochronology and allows for the accurate determination of geological formation age while also providing information on the relative geochemical conditions of deposit formation. For the former, a growth curve for standard lead is generated based on the composition of primordial lead and the constant evolution of lead in the earth's core due to radioactive decay. If, once lead is removed from the core and crystallized into minerals it is separated from U and Th, the evolution of its lead isotope values will stop, as is the case for most lead minerals. This value marks a point on the growth curve that can be attached to absolute time. Because the earth's core is not necessarily homogeneous, and reservoirs may have differing levels of U and Th, several growth curves exist that stack upon one another, depending on the original $^{238}$U/$^{204}$Pb ratio (μ) (Figure 8-4).  By determining the slope of the line (isochron) formed by the relationship between uranogenic and non-radiogenic lead in a given set of related samples,

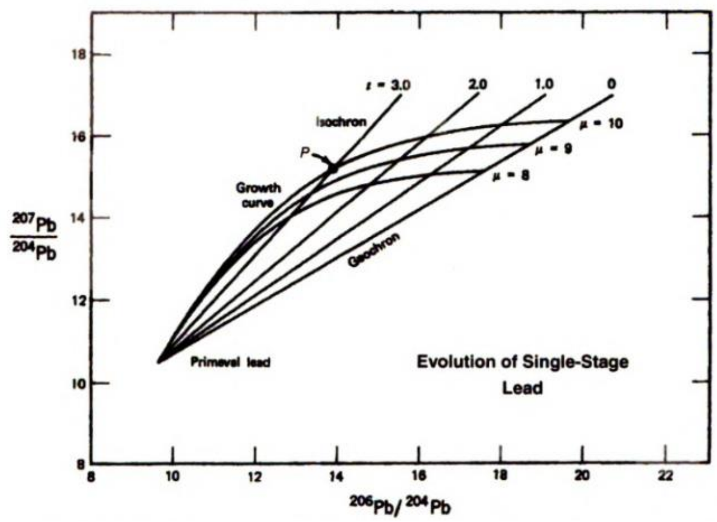


Figure 8-4: Plot illustrating multiple growth curves based on different μ values in relation to a selection of isochrons. Although points falling along a single line may belong to deposits of the same age, their relative vertical position on the line reflects the amount of $^{238}$U present in the geological reservoir that a given sample formed from. As such, where there is a significant break between two groups on a single line – despite being the same age, their original parent material was likely different (adapted from; Faure and Mensing, 2005, p. 262). Note that this image is associated with a single stage lead model, while the Stacey-Kramers (1974) model is more widely accepted. This image is used purely for reference.

an intercept with these growth curves can be established, giving a formation age. Meanwhile, vertical positioning on this isochron provides a further method for differentiating deposits of similar age based on the original $^{238}U/^{204}Pb$ ratio of the parent reservoir (Begemann et al., 2010; Faure and Mensing, 2005, pp. 256–257; Stacey and Kramers, 1975).

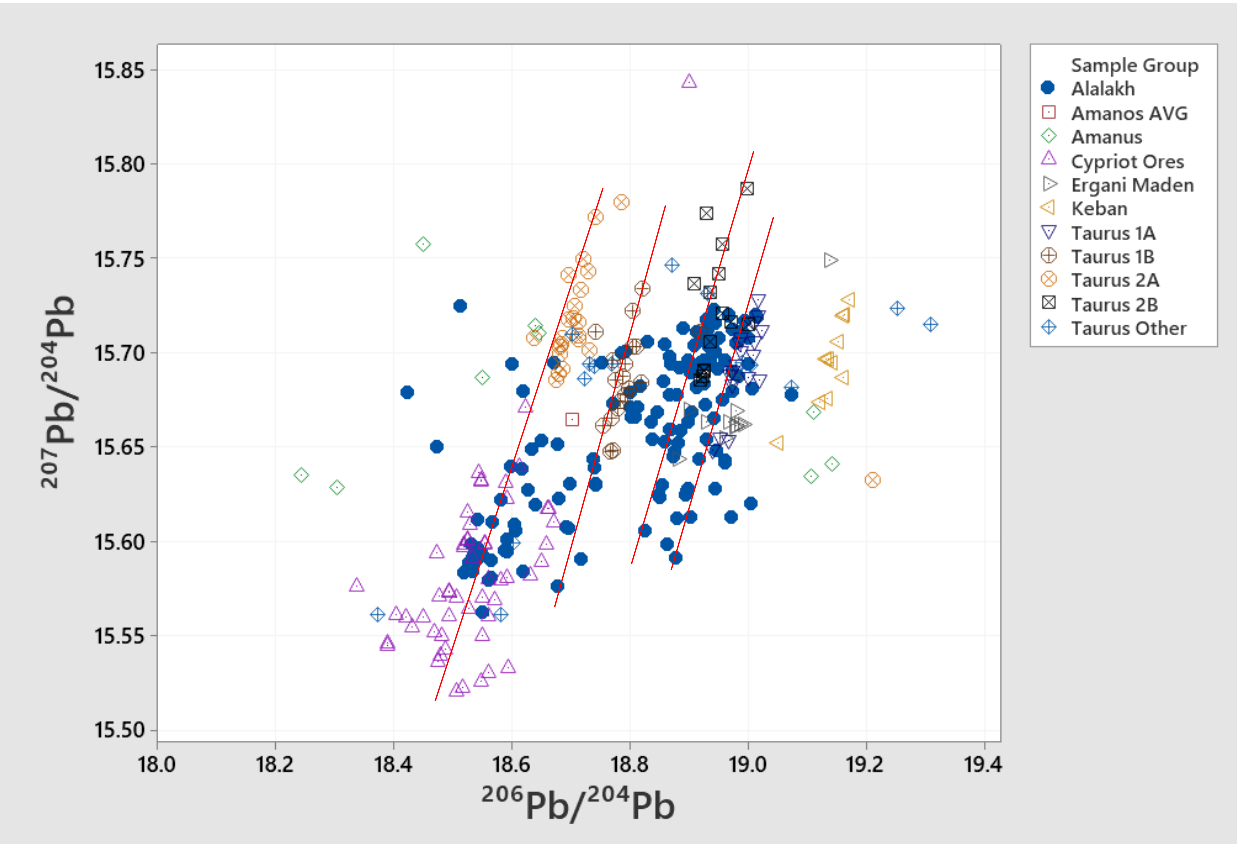



Figure 8-5: Plot displaying $^{204}Pb$-normalized ratios with uranogenic lead including Alalakh samples and relevant ore sources. Amanus AVG is the average point for all of the Amanus ores. As can be seen here, most of the clearly Taurid Alalakh samples originate from deposits with a higher uranogenic lead ratios, while the Amanus sources are extremely variable. As a case in point, the uppermost Amanus point toward the upper-left was shown to host uranium-bearing zircons in the previous chapter. Red lines are meant to illustrate potential isochrons in this data – precise slopes and dates have not been calculated, and some of the steeper features may be artifacts of unusually oxidizing geological conditions or mass-bias effects.

With this in mind, Figure 8-5 displays the $^{204}Pb$ denominated uranogenic lead ratios for the Atchana assemblage and relevant ores. Most of the Alalakh samples fall along two isochrons associated with Taurus 2B and Taurus 1A deposits, containing large amounts of uranogenic lead. The Amanus deposits show an extremely wide spread, reflecting a complex geological history with multiple mineralization events, generally agreeing with the representation given by Akıncı (2009, p. 488). Further, the average of the Amanus points still falls at the upper end of the cluster overlapping with the Cypriot field. Most of the Cypriot ores are too low in uranogenic lead to be source candidates for the Atchana artifacts. Further, where there is potential agreement, a subset of the Taurus Other group continues to bracket, and in one case directly overlaps, with this group. Both the directly overlapping and bracketing points are ores from the Bolkdardağ mining district and, though they do not form a fully characterized field, they can be used to provide the general outlines for one. Since this still results in an ambiguous provenance attribution, it is necessary to turn to the LIA data classified according to the material typology established earlier.

## 8.3 Lead Isotopes by Material Classification

The LIA data considered in reference to specific material classifications established previously provide opportunity both to disambiguate the provenance discussion encountered previously, as well as to reconstruct the metal procurement network of Tell Atchana in greater detail. In the following, only those samples for which I was able to make secure classifications

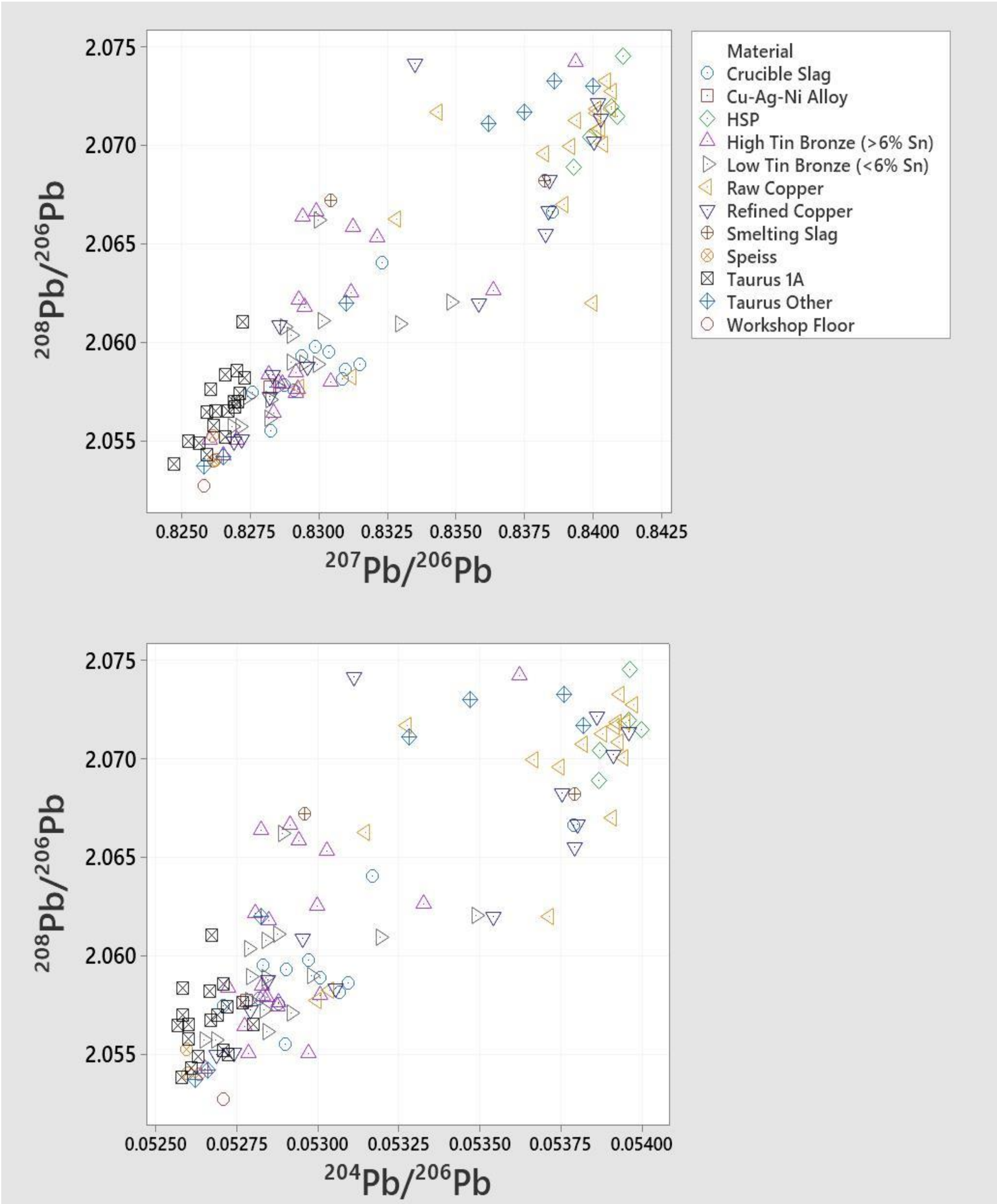



Figure 8-6: Lead isotope plot of Atchana artifacts with material classifications as determined by microscopic and compositional analysis. Taurus 1A and Taurus Other ore values are provided to orient the reader relative to Figure 8-3. The workshop floor sample was part of 4109_2 that was determined not to contain any spilled metal, only fragments of ore as seen in Figure 6-51.

were considered. Figure 8-6, displaying the results of this analysis, highlights several important trends. First, the cluster of material in the upper right that overlaps with the Cypriot ore field includes all samples of HSP, as well as most of the raw copper, some refined copper, a smelting slag (AT4327). All the speiss samples plot to the lower end of the Taurus 1A field, overlapping in particular with the Sulucadere samples. Also included with this material are the bronze samples listed in Table 7-7, with those extending along the upper portion of the blue trend in Figure 8-8 are closely associated with Taurus 2B, which is also primarily Bolkardağ. Finally, the crucible slags are largely contiguous, overlapping with some high and low tin bronzes, trending toward the group in the upper-right corner.

Having established that the material clustered in the upper-right corner corresponds entirely with the category of HSP and one smelting slag – meaning that there are in fact six samples of matching smelting slag – as well as a substantial number of raw and refined copper samples which establishes this material as remnants of a contiguous productive chain, I am in a position to suggest that this material most likely from the south-central Taurus. Although Cyprus cannot be excluded from consideration, my proposal is based on the simple observation that much of this material is primary smelting debris that has not undergone any sort of secondary processing. For this to be considered Cypriot material, one would need to argue that in addition to oxhide and bun ingots, packages of unagglomerated raw copper and slag were also being exported from Cyprus. Given that this material does overlap with the tip of the Apliki deposits, associated by Stos-Gale et al. (1997) with the production of oxhide ingots in the LBA, this would fit the macro-scale narrative of bronze age metal trade discussed in chapter 5. The only modification necessary would be the interesting interpretation that the debris from smelting Apliki ores in Cyprus was being scavenged for export. A similar hypothesis has been put forward

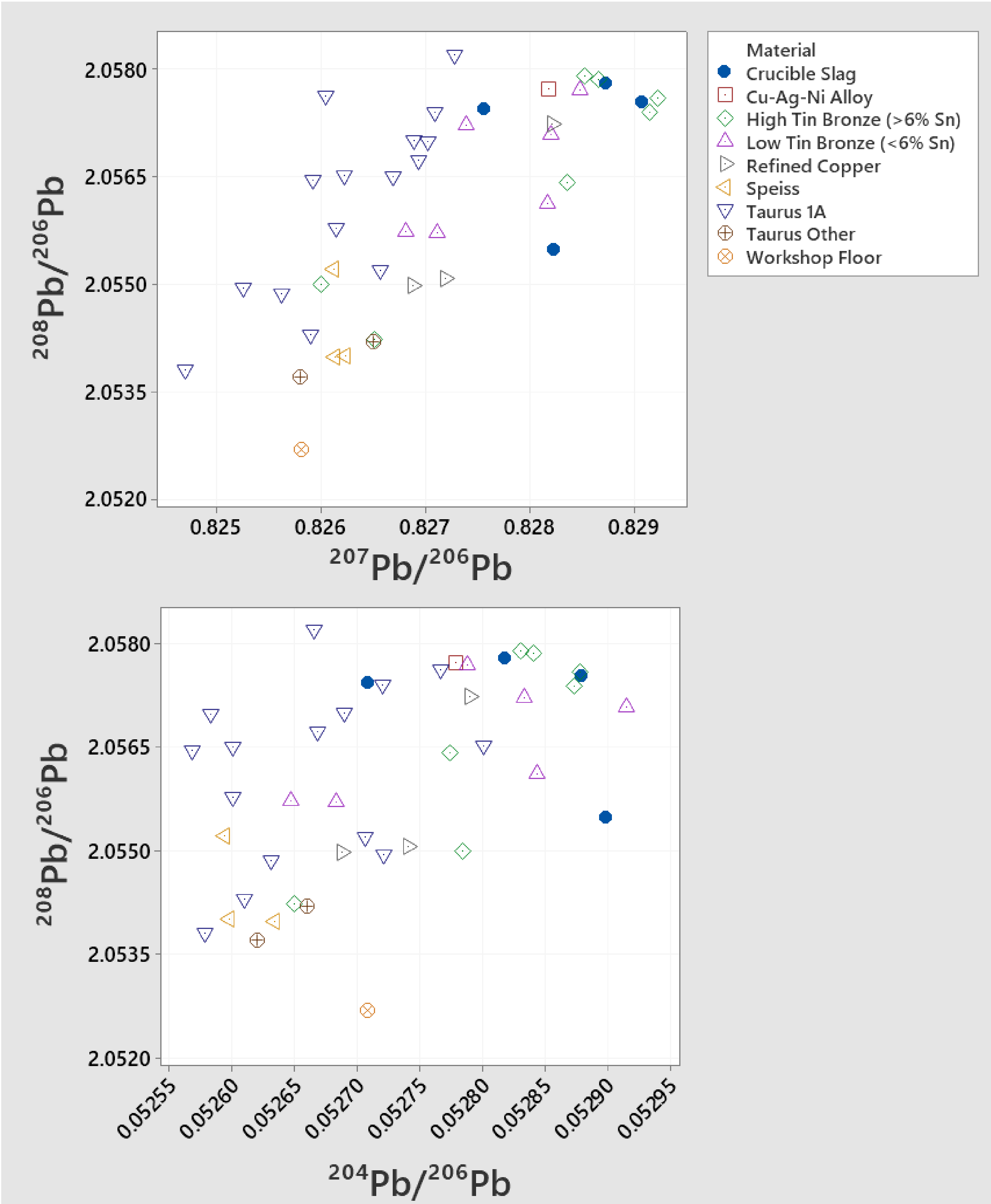



Figure 8-7: Lead isotope plots displaying the lower-left tip of the Taurus 1A field and the associated artifacts from Tell Atchana. Following a line from the speiss samples through the crucible slags leads directly to the group of copper samples in the upper-right of Figure 8-6

for the scavenging of scrap copper in the Negev during the EBA, and so would not be without precedent (Rehren and Pusch, 2012, pp. 218–219). Considering the vast amount of Bolkardağ material already shown in the Alalakh assemblage, however, Occam's razor would lead to the rather simpler explanation that this copper was produced from ores in the same district as much of the other metal at the site, and just so happened to originate from a deposit with a locally atypical isotopic signature. In lieu of more thorough isotopic characterization of the Taurid deposits, we are left to suggest simply that the archaeological evidence leans toward their use as the source for this metal.

A major theme that I have emphasized throughout the analytical results has been the issue of speiss and its potential association with a limited range of the tin bronze assemblage. Beyond this, based on trace element analysis, I also suggested that some of the bronzes may have been produced from stannite (or similar) ores that are known to be present in Bolkardağ at Sulucadere, though the quantities have historically been considered too small for serious consideration as a source of tin during the Bronze Age (Çağatay and Arman, 1989; Wagner et al., 1989; Yener and Özbal, 1987). Though the LI figures cannot definitively prove this link, I believe that when taken in aggregate with the other evidence I have presented thus far, a strong case can be made that complex tin bearing ores from Bolkardağ were being used as part of a very particular technological style for the production of some bronzes at Tell Atchana. In particular, as can be observed in Figure 8-7, all three speiss samples cluster at the very tip of the Taurus 1A ore field. The associated Taurus 1A ore samples are from the site of Sulucadere itself, while the two Taurus Other ore samples nearby are from Alihoca Köy, on the other side of Maden Dere (Dere meaning stream in Turkish), making this district the probable origin for these tin bearing materials.

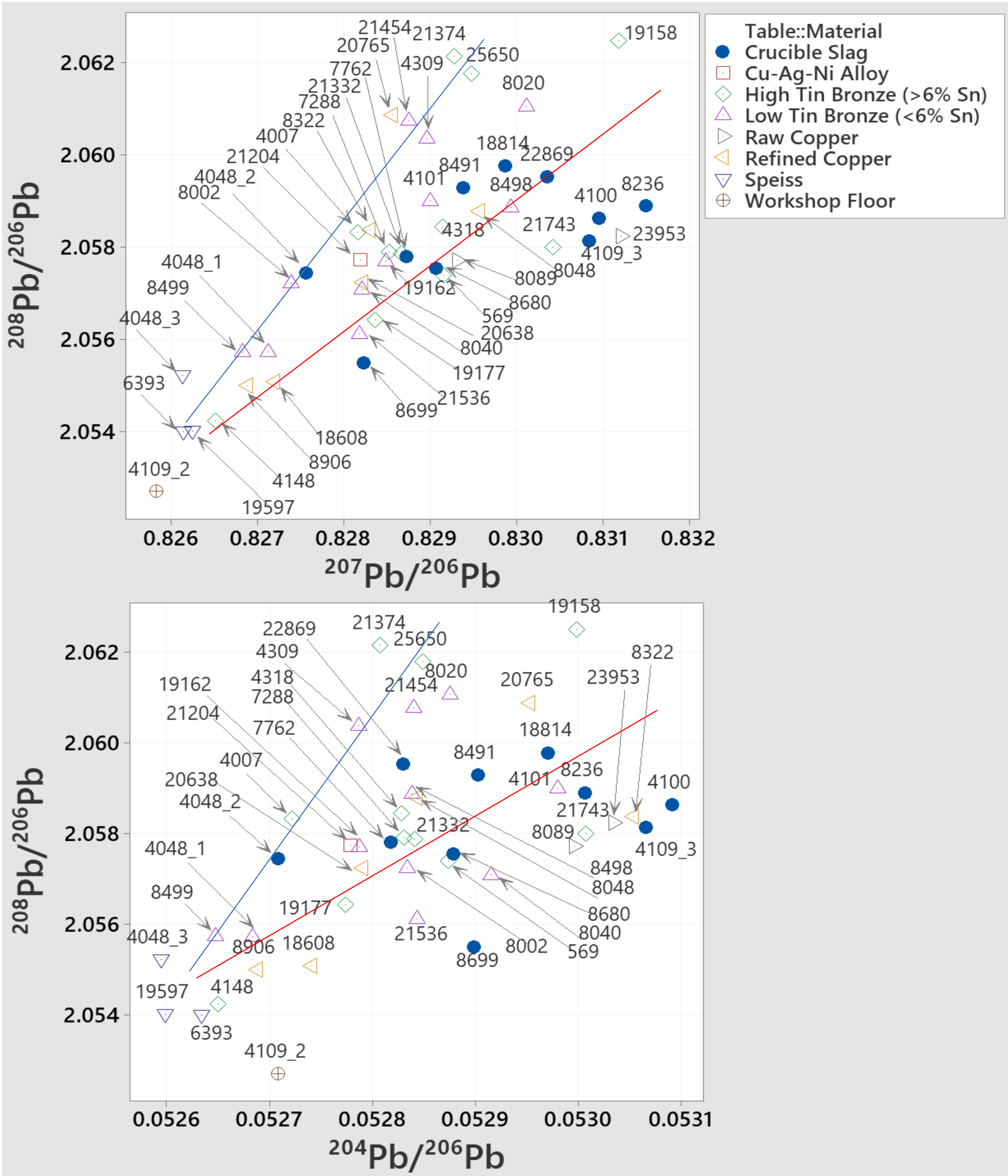



Figure 8-8: Lead isotope plot showing the entire region associated with the Taurus 1A ore field. Two general trends can be observed, with one preceding upward at a steeper angle to the left (blue line) and another at a shallower angle to the right (red line). That the one on the right moves in the direction of the copper field discussed above and is associated with crucible slags suggests that these are the result of active alloying between these different sets of probable Bolkardağ material.

Of the bronzes listed in Table 7-7 as candidates for being speiss-related bronzes based on their elemental composition[5], only AT20433 and AT21510 do not appear to be associated. Given that each of these was close to exclusion from the list, this is not surprising. For 4048_1, which I have postulated previously as being a co-smelted bronze, its position near the speiss samples is another piece of evidence in favor of this close relationship. For the other candidates, they generally fall along the steeper blue trend line in Figure 8-8 which characterizes the region where the Taurus 1A/2B and Atchana samples overlap most closely, with the exception of AT569. This material is likely the result of direct alloying, exemplified in AT4007, with copper from deposits with similar isotopic compositions such as AT8322 or AT20765. Finally, the points along the red trend line would be the result of alloying, as shown through the crucible slags in this region, with copper from the Taurus Other (or Cypriot) sources mentioned previously. The often-significant lead content of the speiss (Table 6-5) and its associated products would then serve to draw the isotopic signature of the finished product toward the Taurus 1A/2B field, resulting in the observed pattern. Though the specific sites mentioned may not be the precise origin for the ores used in these processes, the region and processes involved are reasonably clear, suggesting the use of local tin sources into the LBA.

## 8.4 Site-level Patterns in Lead Isotope Data

Based on our conception of LBA metal industries being largely state-operated or, at the very least, having state managed raw material procurement networks, we have tended to assume that assemblages will be relatively mixed (that is, homogenized) at the level of the site. This is not an unreasonable assumption, but one of the middle-range hypotheses of this project was that

[5] AT 569, 4007, 4048_1, 4101, 4309, 7288, 8499, 20433, 21454, and 21510.

there may be differences between procurement of metals for the palace, and those for the lower-town industries at Tell Atchana. The rationale behind this thinking was that, given nearby ore resources in a landscape that could not be easily governed by lowland authorities, local systems of production would display a certain level of independence. I have already suggested in chapter 4 that this could be a cause of the slight divergence seen in the organization of production between Tell Atchana and other well-known sites in the eastern Mediterranean, with the former appearing less top-down in its structure. In the following, in order to compensate for the larger number of Area 4 samples in the current dataset, this discussion also includes Tell Atchana LIA results from Kurucayırlı (2015) and unpublished data[6] produced by Marc Walton (Getty Institute) and Joseph Lehner (University of Sydney). The result is 92 analyses from Area 4 and a (still somewhat unbalanced) 50 samples from Area 1. Though it is not currently possible to definitively explain all aspects of the pattern, there is a surprising divergence between the Area 1 and 4 assemblages, reinforcing the image of a largely or semi-independent industry in the lower town while the palace industry appears to rely primarily on other material sources and engage in more extensive mixing.

Figure 8-9 displays all the currently available analyses of samples from Tell Atchana, showing that the majority of Area 4 points cluster in two regions, while Area 1 samples have a minor presence. Most Area 1 points fall within a central region (red circles) constituting 33 total samples, 8 of which are from Area 4. This group is composed of a lower dense cluster containing the Area 4 material, while the other forms a less distinct group extending to the upper-right. At

[6] With the permission of K. Aslıhan Yener

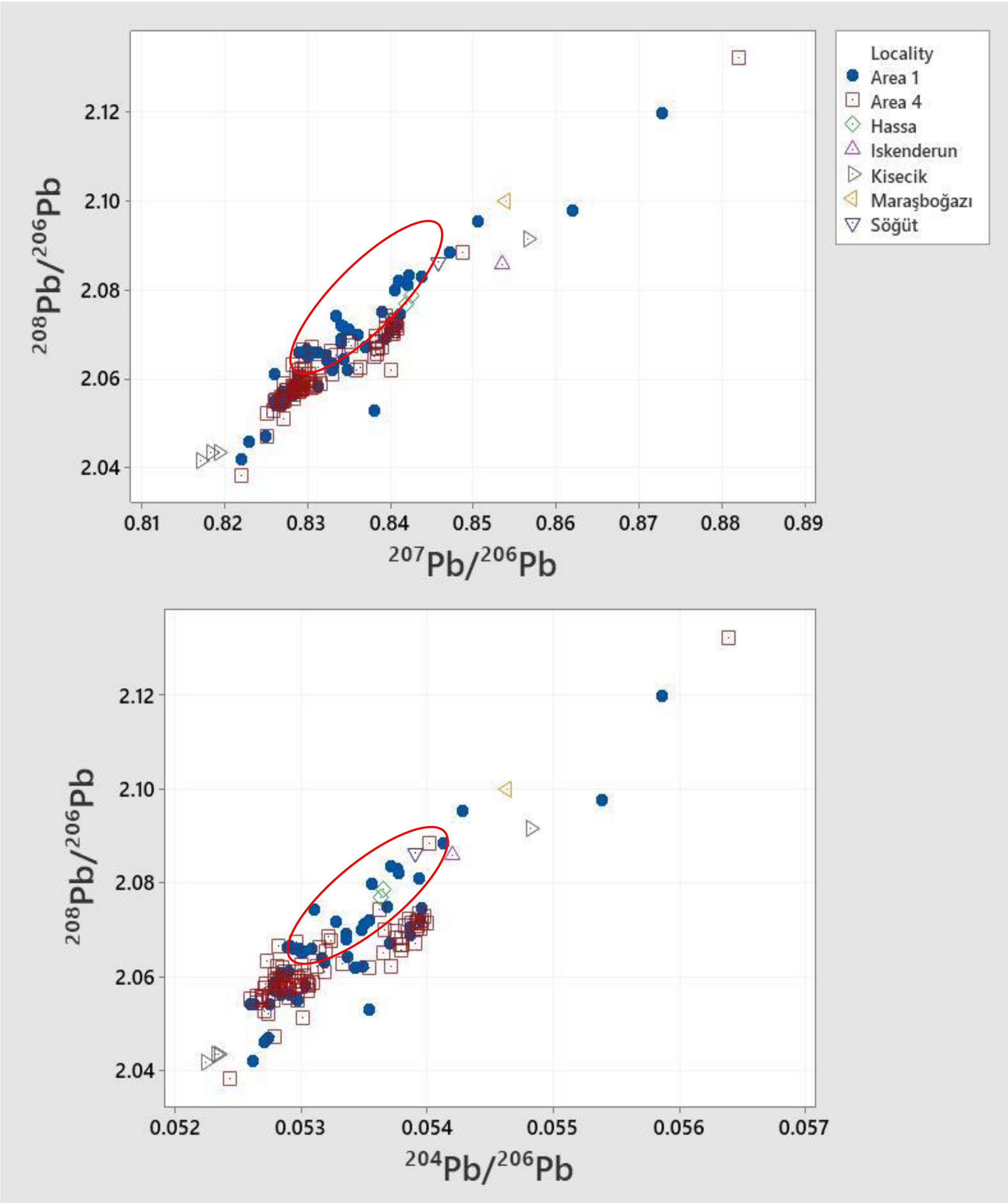



Figure 8-9: Lead isotope plot showing Alalakh samples according to excavation area. Amanus ores are presented here to illustrate their position along a potential mixing trend. The Area 1 samples in the middle could, however, also be associated with some Aegean sources such as Kea or Seriphos. None of the points in this group (including raw copper sample AT8666) show good agreement with currently known ore deposits.

the lower left corner of the plot, a small group of primarily Area 1 samples is near the lower cluster of Kisecik ores, though the relationship is tenuous.

Not represented on the plots here, the central group does partially overlap with some ore sources and copper slags in the Cyclades such as Seriphos and Kea at its lower end (Webb et al., 2006). Nevertheless, the associations are not especially convincing since the groups largely disarticulate in the $^{208/206}$Pb vs. $^{207/206}$Pb plots. Further, in keeping with the spirit of simplicity, the upper end of the group is consistent with Amanus ores from Hassa and nearby Söğüt, while the lower end could include mixed smelting of variable Amanus ores and some recycling involving the Taurid material based on its lateral distribution relative to the primary trend of the data which would result from mixing of Amanus material with the broader spread of Taurid material. This is then illustrated by the greater overlap of Area 1 and 4 material in this region, where the two source pools are combined.

The two clusters of Area 4 samples have already been discussed at length in terms of their provenance, with the lower being closely tied to the Taurus 1A/2B groups associated with Bolkardağ. The upper cluster has a less certain provenance, occurring at and extending beyond the very tip of Cypriot Solea Axis ores (Stos-Gale et al., 1997), while also agreeing with a set of southern Taurid ores that appear as distinct from the Taurus 1A/2B groups. Based on archaeological and analytical considerations, I have tentatively assigned this material a Taurid provenance. If one wishes to reject this assertion, an explanation must be provided as to why the Area 4 workshop has primary access to Cypriot sources, while the palace rarely uses this material. The lower of these clusters contains a total of 55 samples, of which 13 originated from palace and temple annex contexts. Meanwhile, the upper group hosts 28 samples, five of which are from the palace and temple annex. This would mean that, of the 142 samples in the primary cluster on the plot, only 18% overlap with samples of different excavation areas.

If we accept the hypothesis that the upper part of the central group is a result of smelting Amanus ores with highly variable LI compositions, this would indicate that the palace assemblage is based primarily on the use of metal smelted from ores available along the edge of the Amuq valley. If, however, we reject this hypothesis and move in favor of one of the Aegean sources – which is plausible given Alalakh's established links to the Aegean (Yener, 2015b) – we are still left arguing that the palace was utilizing primarily traded material. Meanwhile, the evidence presented in this chapter and previously suggests that the Area 4 workshop material consists primarily of relatively unmixed metal that still plots in proximity to its original ore deposits, excepting the material intermingled with crucible slags mentioned above.

Finally, at the lower left corner of Figure 8-8 is a point for 4109_2 – the workshop floor from Area 4. I selected a fragment of this sample for analysis based on the absence of metal and confirmed presence of ore minerals. The result should be taken cautiously, given the wide range of options for depositional contamination. That it plots at the lower end of the Taurus 1A group is striking, however, and even if taken only as a general reference, would reinforce the hypothesis that Taurid ores were being brought all the way to Alalakh and used in a primarily non-palatial industry. Further, that a prill embedded in another section of this sample plots to the mixed region of the central field suggests that contamination due to corrosion of embedded metal may not be a significant problem. In short, this sample should reflect an average primarily of the ores embedded in the soil matrix, the soil itself, and aggregate lead contamination from metallurgical processes carried out in Area 4, with the result being a heavily Taurid (and possibly Kisecik) influenced signature.

While this explanation is reasonably coherent, there remains the issue of the two ore samples excavated from the site, the Cu-Pb ore being from Area 4, and the Pb ore (galena) being from Area 1. Given the hypothesized association of palace and temple metals with these Amanus ores, the latter is relatively unproblematic. For the Cu-Pb ore, from a context within the Area 4 compound during the height of its activity in Period 3, there are several unusual possibilities, none of which I find especially satisfying. One is that the lower range of the central group includes co-smelting of Taurid and Amanus material in the Area 4 workshop, with the final product being used almost exclusively in the palace. In such a case, the Area 4 workshop would be periodically handling batches of ore destined for palace consumption alongside their own southern Taurid material and this may well have been work conducted as part of a labor obligation that has simply not appeared in the textual record. From a practical perspective, this strains credulity and there is little in the archaeological literature that speaks to this detailed level of analysis. From a technological style perspective, one could argue that these craftspeople were seeking out Taurid ores for production according to their own internalized style, while the exploitation of Amanus material for official purposes stemmed from its proximity to the site and a desire for expediency in completing work obligations. Rather anticlimactically, another option is that this ore fragment made it into the workshop by accident. Since there is not enough evidence to fully support or refute either option, I leave it to the reader.

## 8.5 Conclusion

From a provenance perspective, the samples from Tell Atchana reflect primary metal sourcing from the south-central Taurus, with eastern Taurid sources such as Keban and Ergani Maden being easily excluded based on LI data. More ambiguous are samples that may be related to Cypriot ores, though archaeological and analytical considerations do not strongly support this, instead pointing to atypical Taurid ores, also in the Bolkardağ area. This being said, Kuruçayırlı (2015, p. 260), has reached a significantly different conclusion, linking the assemblages of Kinet Höyük, Tarsus, and Tell Atchana to Cypriot deposits at Kalavassos, Limassol, and Limni. However, this investigation does not include the new Amanus data, nor the Taurus Other samples discussed here (see; Budd et al., 1995 on excluding "outlier" ore analyses). On this point, the extension of some samples to the right of the Taurus 1A field was used to suggest a tentative association between many of the Tell Atchana samples and the Kalavassos I ore deposit. Having now demonstrated that many of these samples are also intermingled with crucible slags, this is likely erroneous, the observed pattern being due to mixed lead signatures.

Within the overall assemblage at Tell Atchana, there appear to be two different networks in operation, one serving the palace that is more amorphous in shape, not lending itself to secure provenance determinations, and another in operation in the Area 4 workshop that clusters around southern Taurid deposits in the Bolkardağ area. Compared against the LBA assemblage from Boğazköy (Lehner, 2015, p. 186), the procurement networks of the Hittite capitol appear to place greater emphasis on the Taurus 1B/2A groups, located primarily in the Aladağ range, while their narrow distribution along a defined trend – as opposed to clustering around individual ore groups – may suggest a more mixed metal pool (Figure 8-10). When considered alongside the data from contemporary sites in Cilicia, this pattern is further reinforced with the Cilician, Alalakh palace, and Boğazköy assemblages primarily occupying the middle-range cluster. Setting aside the Amanus provenance hypotheses put forward in the above discussion, it is possible that this material represents the circulation of mixed, multi-source “royal” metal. Though the existence of parallel procurement networks supplying different levels of society has been hypothesized elsewhere (Rehren and Pusch, 2012), it has rarely been considered that two parallel systems of organization for almost the entire *chaîne opératoire* could persist in a single urban center with a palace economy. This supports the idea that the metal economies reflected in ancient texts were based on resource acquisition from a broad and unstructured network of producers, with segments of the metallurgical industry in some regions acting on a largely independent basis.

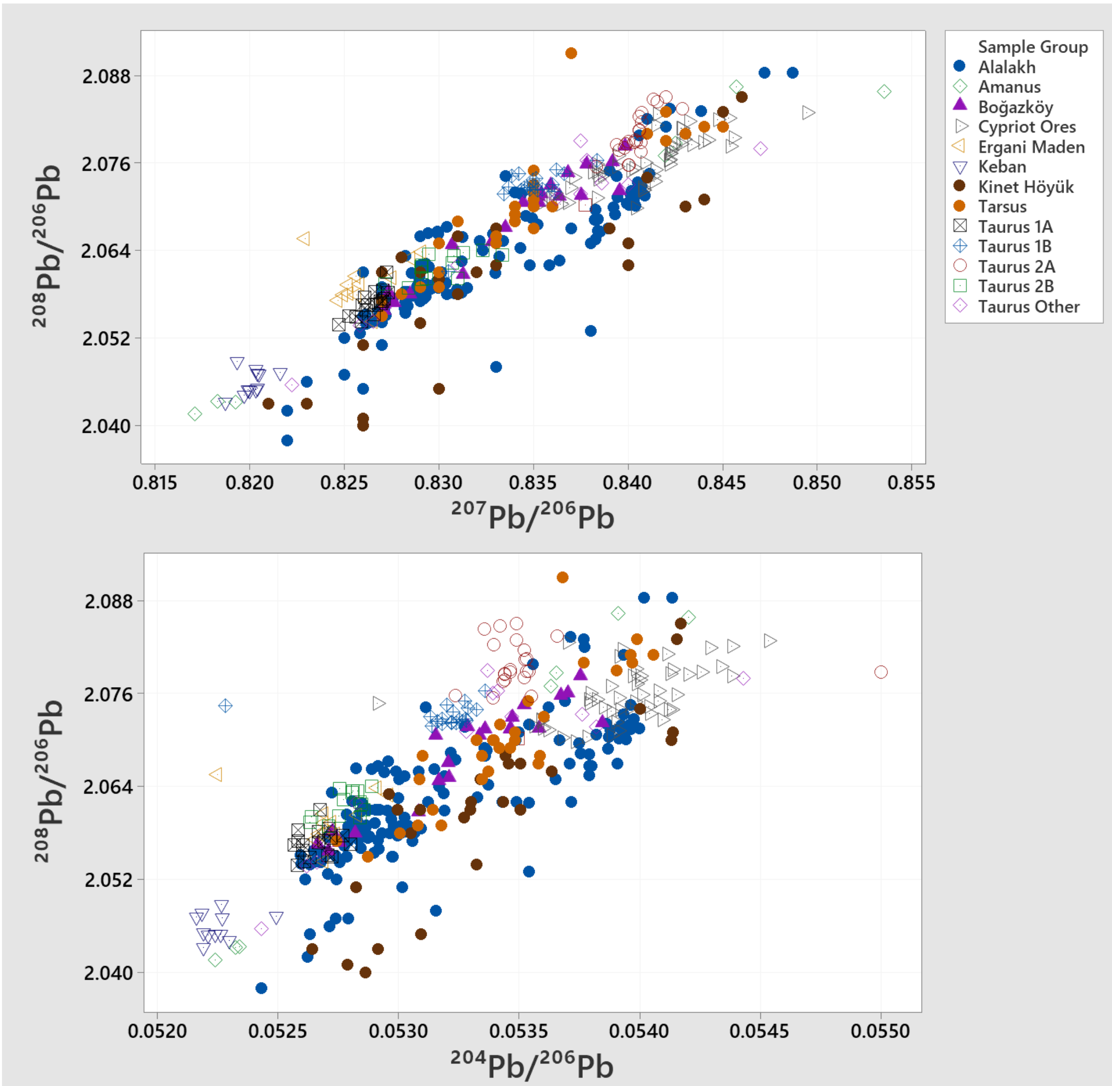


Figure 8-10: Lead isotope plot displaying Alalakh, Boğazköy, Kinet Höyük, and Tarsus data alongside ore sources discussed in the text. Both the Kinet Höyük and Tarsus data include LBI and MB material.

As a final point, this discussion has provided further support for the presence of a unique technological style surrounding the production of bronze at Tell Atchana involving the use of Taurid tin. In terms of clustering, the LI results closely reflect the trace element data presented in the previous chapter showing distinct compositions for copper versus a range of likely directly produced bronzes, as well as a mixing range for actively alloyed bronze. This has then been presented at the specific process level in the optical and scanning microscopic data. Though a significant consideration in its own right, the regional context appears to suggest that Tell Atchana, and the Area 4 workshop in particular, may be the most intensive user of the resources involved in this technology (Kuruçayırlı, 2015, p. 226). Though the $^{208/206}Pb$ vs. $^{207/206}Pb$ plot of Figure 8-10 shows Alalakh, Kinet Höyük, and Tarsus overlapping with the Taurus 1A/2B fields, their disarticulation in the $^{208/206}Pb$ vs. $^{204/206}Pb$ shows that the majority of Cilician metals in the relevant section of the plot fall into the mixing field for bronze production. Compared to the Alalakh data, which shows a continuous pattern from Taurus 1A/2B into this mixing field that may be associated with the extensive productive chain illustrated at Alalakh, this would paradoxically suggest that the Cilian sites, located closer to the ore deposits in question, were receiving their material from the same networks as the Alalakh Palace. Given the large difference in sample size, this could also simply be a result of sampling bias.

# 9 Spatio-Temporal Analysis

I have focused primarily on the analytical data up to this point to provide a detailed picture of the technical processes in practice at the city of Alalakh over the course of the Late Bronze Age and into the very beginning of the Early Iron Age, covering a span from approximately 1550 to 1150 BC. In the interest of clarity, I pursued this discussion with minimal consideration of spatial and temporal patterns in the data to put more of a focus on the various *chaîne opératoires* in practice. Turning back to the discussion initiated in chapter 2, if the previous chapters provided answers the questions of technical practices, this analysis is meant to contextualize them in terms of the organization of production. The result shows that the Area 4 industry is more of a complex multi-craft industry, closely reflecting Costin's (Costin, 1991, pp. 8–10) concept of community or large household workshops. For Area 1 the picture is somewhat less clear, though based on the similarity of some workspaces with the Area 4 context and the divergence of others, a combination of nucleated corveé as well as retainer workshops seems probable. This pattern of organization appears to remain remarkably durable over this 400-year span in Area 4 and suggests entrenched concepts of technology and organization.

I had originally intended to pursue this aim through a spatial statistical analysis of the analytical data to identify clusters of samples defined by elemental compositions related to provenance and technical processes. The result would then have hypothetically allowed for a classification of workspaces according provenance networks as well as the processes being carried out. A fundamental assumption here, however, is that ancient craftspeople would discretely classify space for specific processes and that enough material would be left to create a coherent enough assemblage to identify such patterns. These efforts failed to yield positive results.

This stems from two general problems with the dataset under consideration. The first issue is that, when developing the original research design for this project, the sheer variety of material was hardly anticipated. While a dataset of 100 objects would have been enough for basic analysis if there were only three of four classes of material, the range of material and processes seen here meant that there were only a limited number of samples from each material type. Going hand-in-hand with the first issue, the relatively diffuse spatial patterning of the sampled material meant that identified patterns were at such large scales that they were not meaningful. In this we come across an interesting conflict where the requirements of spatial statistics (a sufficiently large dataset at an appropriate scale) are at odds with what is reasonably possible to accomplish in terms of metallurgical analysis given constraints of time and money. In the following section I provide an assessment of the application of spatial statistics to archaeometric data and the problems I encountered. The reader should feel free to proceed immediately to section 9.2 if this is not of interest.

The work of spatial and temporal analysis becomes significantly simpler and more intuitive when conducted through direct observation of object distributions and assemblage composition. Through a simple Period-by-Period discussion of finds, their general distribution within the site and within specific areas, and their technological characteristics, we can still come to a satisfactory discussion of organization of production in the city over time and space without the need for complex statistical testing. As a result, the discussion will take on a more narrative tone than originally intended, proceeding by periods starting with Period 5 and ending with the very beginning of Period 0[1], followed by a brief consideration of some compositional trends, and ending with a few notes on pyrotechnical features. Because Area 4 comprises a contiguous unit, it will be dealt with as such the following discussion, while Area 1 will generally be handled on a square-by-square basis.

## 9.1 GIS Methods:

In applying spatial statistics methods to the compositional dataset, I attempted several different approaches with the goal of investigating whether there were patterns either in raw material use or the technologies employed in the production of finished goods. To this end, I employed exploratory regression analysis, cluster and outlier analysis (Anselin Moran's I), hotspot analysis (Getis-Ord Gi), and Grouping Analysis.

As the name suggests, exploratory regression performs a series of regression analyses on a dataset based on a series of user-defined variables. Rather than requiring the researcher to manually conduct analysis on different combinations of variables, this tool systematically goes through each combination and then subjects the resulting Ordinary Least Squares models to a series of statistical evaluations to verify their applicability. While this tool is not itself spatial in nature, it is generally used as a first step in data analysis to assist in identifying patterns that may then be investigated spatially (Mitchell, 2009). In this case, I applied exploratory regression to both the SEM-EDS compositional datasets as well as the LA-ICP-MS dataset. In both cases only a small handful of models were generated that passed all subsequent testing, however, these were based on trends that had already been identified as significant during PCA analysis, such as that

[1] Periods 5 and 1 will be rather cursory in nature due to the small number of samples.

between iron and sulfur. In most cases, however, the models failed on at least the Jaque-Bera test of normal residual distribution, if not more.

Given that no reasonable models were forthcoming when the data was considered independent of temporal distinctions, I opted to abandon this avenue of investigation. Ultimately, the failure of this analysis is probably due to two factors. First, exploratory regression is typically suggested for larger datasets in the hundreds of data-points. Not only was this dataset only 105 points, but the heterogeneity of the assemblage means that the number of points for which we might expect any sort of significant relationship, that is, the number of objects falling into any one material category, is well below that. This brings us to the second point, which is that regression analysis is typically quite sensitive to outliers, of which this assemblage has many. As such, while it may be fruitful to apply exploratory regression to individual material categories, the associated datasets are so small that the results would still be questionable in terms of representativeness.

Cluster and outlier analysis is a modification of the Moran's I spatial autocorrelation statistic that is meant to be more sensitive to local neighborhood variation (Anselin, 1995). At a basic level, this method serves to identify clusters of high and low values for a given input, first by looking for similarly high or low values within a given or calculated threshold distance, defined by either a positive or negative Moran's I-value. Each point within a cluster is then assigned a z-value and p-value to assess the statistical significance of its association with the cluster. This assessment being based on a 95% confidence interval, those points with a p-value in excess of 0.05 are then deemed statistically insignificant and excluded from the cluster. A likely issue in the application of this method to the dataset here has to with its significant sensitivity to sample size, requiring at least 30 datapoints. Though the overall sample here surpassed that number, no single class of material in the assemblage met this requirement. In a setting where I was essentially testing for spatial clustering of material categories, this ultimately violated the requirements of the method.

In the case of the analysis attempted here, I wanted to explore whether elements and elemental ratios related to raw materials and technical processes would form meaningful spatial patterns within various workshop contexts. As such, I applied this method to values for Ni, As, Ag, Ni/Ag, As/Sb, and Ni/Co with a threshold distance of 8 meters, since this accounted for the size of some of the larger contiguous spaces on the site. Realistically, since many metallurgical activities are dependent on being near a heat source, and therefore likely spatially circumscribed, this value is probably overly generous. While some of these analyses did produce clusters, the majority of points tended to have p-values well in excess of 0.05, and as a result were deemed statistically insignificant.

Two analyses, the SEM results for iron and the As/Sb ratio based on ICP-MS data, returned substantial clusters and bear some comment. In the case of the former, the clustering is largely predicted by the material type as determined by microscopy and PCA. Refined copper and bronzes are seen to form low value clusters, which is fully expected given that these materials have typically undergone secondary refining or melting processes. However, upon closer inspection, two points come to the fore. First, some points are deemed statistically insignificant that have iron contents of zero and fall within other clusters of zero-iron or very low iron contents. Second, some objects with high iron contents of 1.41 wt.% are included in low value clusters, though on technical grounds such materials have no business being classified alongside objects with no iron. In a similar fashion, when we examine the clusters formed based on As/Sb ratios, we also find objects with a ratio of 1 being grouped in with samples having a ratio of 13. Thus, we are faced with a situation where not only are relevant points excluded from clusters for unclear reasons, but other points are grouped in ways that are largely irrelevant to either technical or provenance concerns.

In similar fashion to cluster and outlier analysis, hotspot analysis is another spatial autocorrelation statistic (Getis-Ord Gi*) that involves the identification of statistically significant clusters of high or low values for a specified variable (i.e. an elemental ratio) on the basis of associated p and z-scores. The primary difference between the two, however, is that hotspot analysis measures the degree of association between points within a given radius of the original point being investigated with the analysis proceeding iteratively (Getis and Ord, 1992). This means that if we come across an object with an especially high value for a variable, it will skew the average of the data such that it will create its own hotspot. By contrast, cluster analysis would simply identify this as a high value outlier surrounded by low values. The failure of either method to identify clusters, is a function of a highly diverse sample set being skewed by a few very high values that are not distributed in a regular way.

One method that displayed some promise and will see limited employment in the discussion below is grouping analysis. When employed without a spatial constraint, a K-means algorithm is used to group points based on a theoretically unlimited number of user-specified variables. To form groups, this method attempts to maximize intra-group similarity and inter-group differences. Since this is not actually a strictly spatial technique, the effect is similar to cluster analysis or K-means analysis methods seen in other statistics packages such as Minitab. However, the version seen in ArcGIS also allows for the specification of spatial parameters that aid in specifying the scale of analysis. Even if no spatial constraint is specified, there is an implied spatial component in that the K-means algorithm will still select a random seed location for each group. For inclusion in a group, there must be at least one similar proximal nearest neighbor, which is likely why this method performs better than entirely non-spatial cluster analyses.

As part of the output from this analysis, a report is generated that provides several important pieces of data. First, an $R^2$ score for each variable is generated, wherein higher values indicate a better capacity for a given variable to discriminate between groups, providing a means for evaluating appropriate variables for analysis. Second, while the user ultimately determines the number of groups that should be created, a pseudo F-score plot is generated that may be used to suggest the number of groups between 1 and 15 that ideally suits the data at hand. Nevertheless, the lack of a confidence interval or other metric for evaluating the robustness of the test and the trial-by-error approach to group number and variable selection make this more of an exploratory tool for suggesting potential clusters, rather than a robust analytical method.

In the case of the present work, I utilized grouping analysis employing both trace element ratios as well as individual and groups of trace elements on their own. Several analyses were made using no spatial constraint as well as with a specified nine-meter constraint (the size of our excavation units). The initial number of starting groups in each case was five, mirroring the number of material categories determined in previous chapters. Keeping in line with best practices, I generally started with a single variable and built from there through further iterations of the process.

Although some of the groups defined by this method had internal variations up to two orders of magnitude, other results proved to be more or less satisfactory. While I would not use the classifications as they were provided, they did suggest several starting points. As a case in point, we may look at a plot (Figure 9-1) of the results of grouping analysis for Ni-Co-Ag and see that most of the groups[2] do appear to be reasonable, largely mirroring material categories, though with a lower degree of precision than PCA. Furthermore, though the method can theoretically use an unlimited number of variables for grouping, I have tended to stick to three variables to be able to check their distribution on a scatterplot.

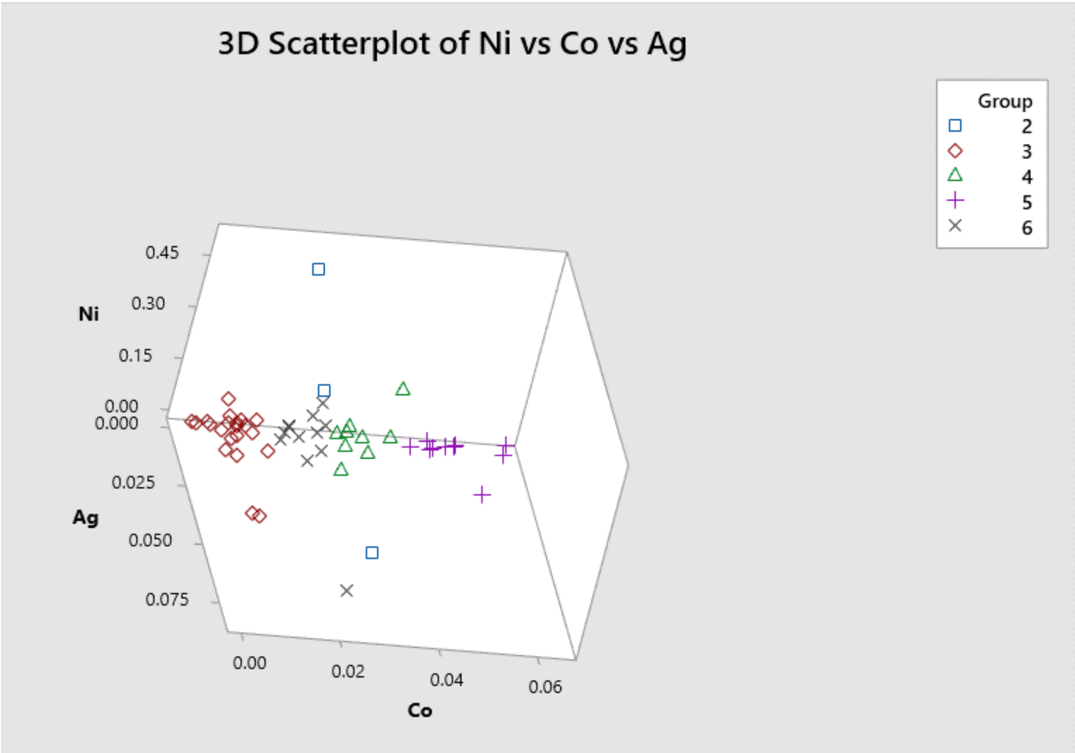



Figure 9-1: 3D scatterplot showing results of ArcGIS grouping analysis for Ni-Ag-Co.

Finally, the fact that grouping analysis in ArcGIS without spatial constraints utilizes a K-means algorithm meant that it was possible to make a direct comparison with a K-means cluster

[2] Group 1 is not shown here because it consisted of a single point for AT21204 (Cu-Ag-Ni Alloy).

analysis conducted in Minitab. The results, plotted in Figure 9-2, were striking in the extent to which the ArcGIS tool was able to achieve a much greater level of resolution in distinguishing groups. In this case, groups 3 and 8 consisted of individual points among the outliers that I merged into the nearby outlier groups. Given that both methods use the same basic algorithm for group construction, the most likely reason for this variation is that growing clusters with an

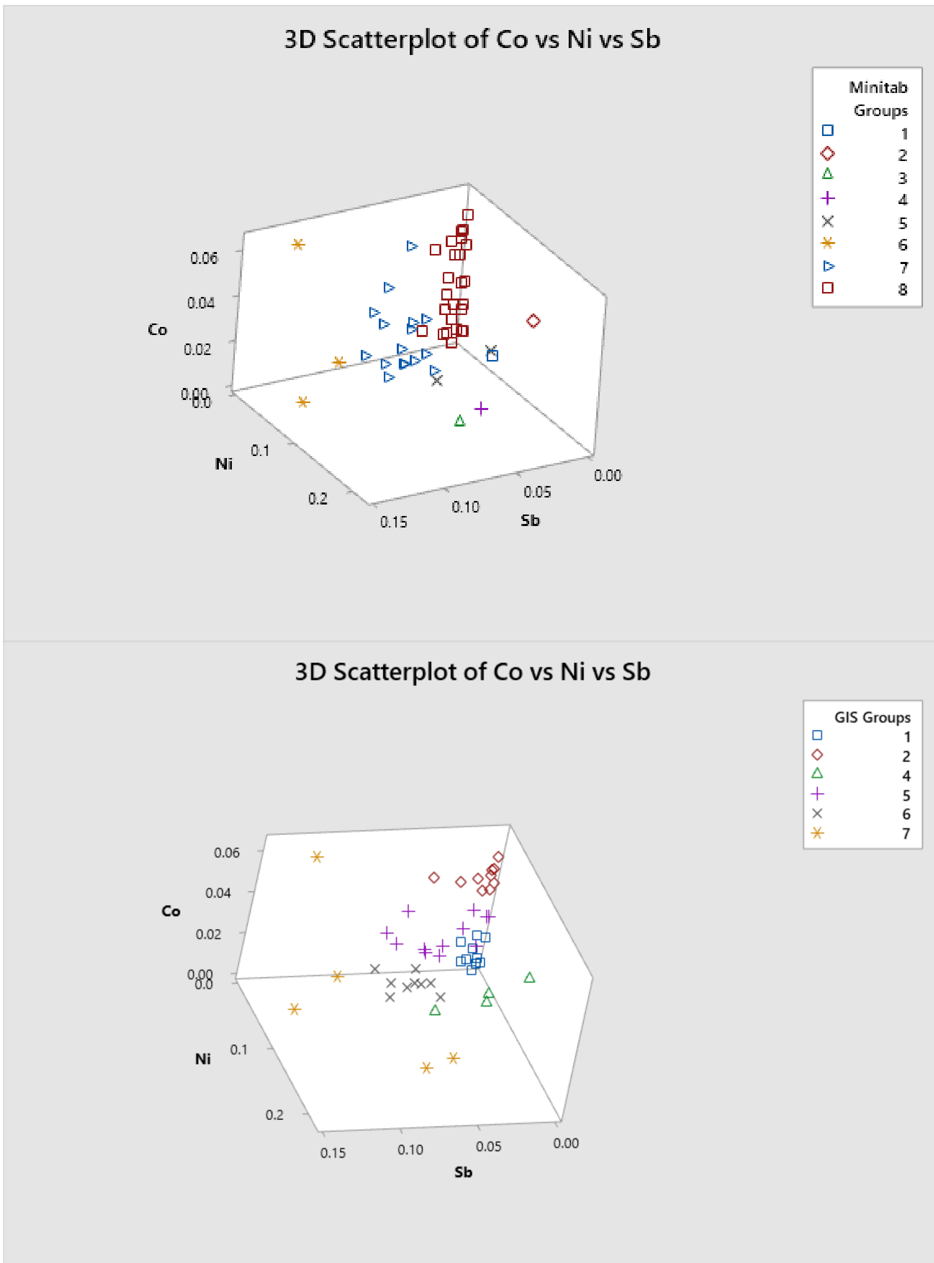



Figure 9-2: K-means groups as determined with the grouping analysis tool in ArcGIS versus that generated by the cluster K-means tool.

included factor of spatial proximity, rather than treating the assemblage as an essentially random distribution, allows ArcGIS to more effectively identify patterns of slight variation.

In sum, it is encouraging to see multiple methods generate similar results in material classification. The attempt at determining spatial patterns within this data was disappointing, however. It seems most probable that this failure was due to diversity inherent to the assemblage itself, as well as a mismatch between the level of analysis desired and the sampling strategy employed. For a future study to reliably map structure-level variation in the use of space, a significantly larger sample size would be necessary.

## 9.2 Periodized Spatial Analysis:

In the following section I will undertake a period-by-period discussion of the Area 1 and 4 metal assemblage for Periods 5 through the commencement of Period 0 in relation to the associated small finds assemblage. One of the primary assumptions I am making here is that the analytical results for my comparatively small sample size can be generally extrapolated to the broader metal assemblage. Given the variety of technical methods reflected among my results, I believe this is a reasonable approach within limits, allowing us to account for most activities taking place at a given time. If anything, we may be missing an even more diverse technological system than my small number of samples can show.

Figure 1-1 displays the chronology of the new Tell Atchana periodization within a regional framework. The span considered here covers roughly the mid-16$^{th}$ C. BC to the beginning of the 12$^{th}$ C. BC. Regarding the presentation of top plans in this chapter, I have opted for un-annotated illustrations for the sake of simplicity. They are, however, identical to those given in chapter 3, and so for specific loci, feature identifications, and elevations the reader may look there if they find that information useful. As a final note, the local phases used here for Area 4 follow the hypothetical phasing outlined in chapter 3 because this division is better supported by architecture, finds distribution, and variations in the pottery sequence.

### *9.2.1 Period 5:*

As far as the assemblage presented here is concerned, Period 5 is represented in trenches 64.72 and 64.73 in Area 4. This period is analogous to local phase 5 in Area 4 and is characterized by a series of seemingly *ad hoc* constructions. After excavation work in 64.73 in 2019, we were able to establish a more coherent sequence for what immediately preceded phase 5 in Area 4. First, our suggestion that the initial phase of metallurgical activity took place within the ruins of a preceding structure proved to be well founded. What is tentatively termed phase 5b proved to be a structure that had been completely cleaned out and burnt. As in 64.72, this event was accompanied by a spate of burials, including a very large number of infants, many of which were disarticulated. As in 64.72, this phase of occupation yielded no more than a small handful of metal finds and no slag whatsoever, while the architecture represents a complete departure from that seen in later phases. As such, we can say with certainty that Period 5 is when metalworking begins in Area 4, among the ruins of the earlier building. This is a theme seen elsewhere in the Near East (Boroffka et al., 2011, pp. 28–39), and is also repeated in Area 1 for later periods.

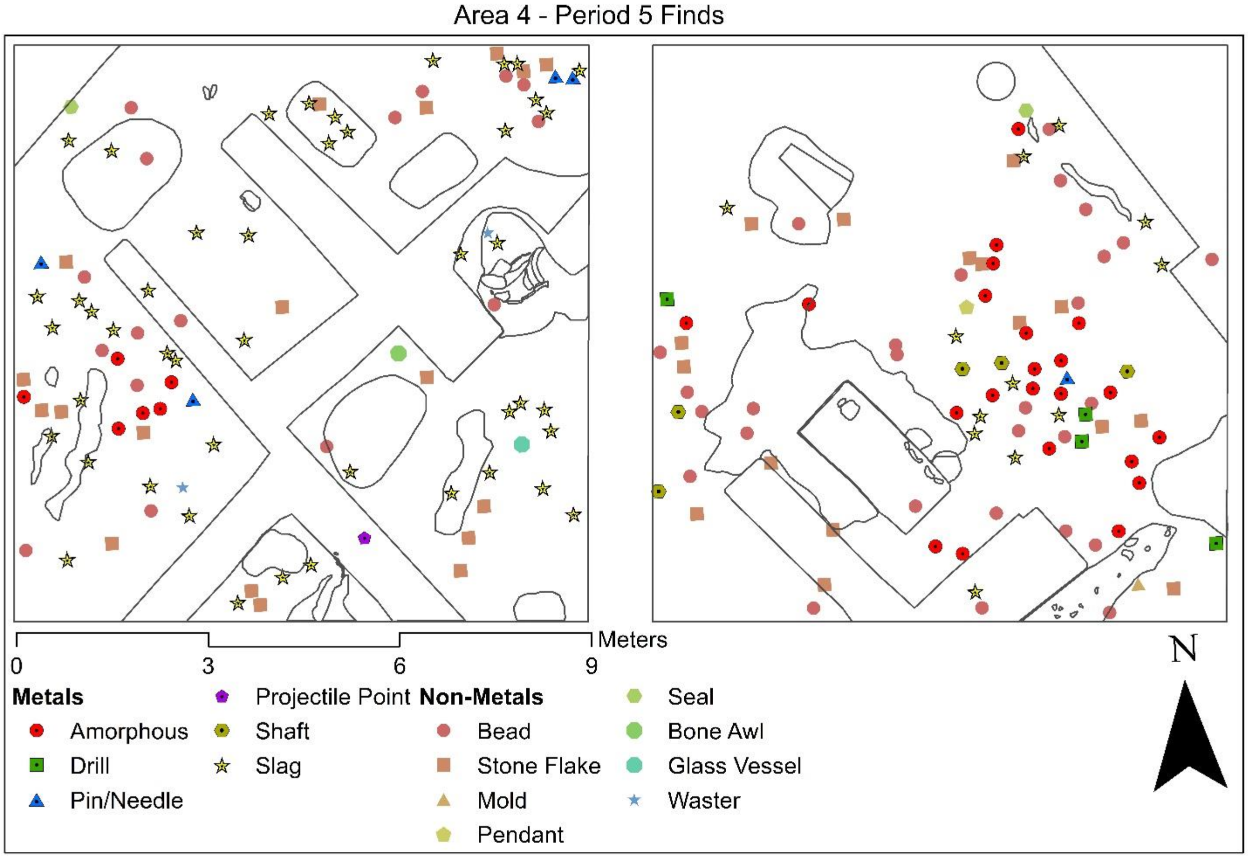



Figure 9-3: Top plan showing locations of metal and non-metal finds from Squares 64.72 and 73, Area 4, Period 5. © 2020 Alalakh Archives

As might be expected from a minor, relatively poor workshop area, the small finds for Period 5 in Area 4 are limited in number, consisting of only about 200 objects including metal, slag, chipped stone debitage, and beads. Of these, 45 objects were metal and 58 were slag (Figure 9-3). Within the metal assemblage, most were amorphous fragments, some of which were large globules (AT25628), while others proved to be bent up clusters of sheet metal (AT25687 and AT25644), possibly for recycling. While the slag was rather widely dispersed, the metal finds were concentrated in two clusters, with the largest being situated in front of what we identified as a platform hosting two furnaces. Laying immediately atop the metal finds, large chunks of furnace wall matching those still attached to the platform were also found, suggesting that prior to the construction of the Period 4 building, the existing features of this phase were knocked down and spread out. In conjunction with the find of a mold fragment nearby, we may suggest that this area was likely used for the casting and refining of copper, the amorphous fragments being either casting spill or unprocessed material awaiting refining.

Though only three objects from the metal assemblage here were sampled, AT25628 already shows how a substantial vein of continuity can be traced through to the later stages of occupation at the site. This amorphous fragment, though completely corroded, displays a microstructure that may be unequivocally identified as a fragment of raw copper. Within the matrix of copper oxides, large globules of iron hydroxides are clearly identifiable, which would have been inclusions of metallic iron prior to corrosion. While we cannot point to local smelting at this early stage, the basic product in use is unprocessed copper found not in the form of ingots, but rather as small agglomerations of raw metal.

In addition to prefiguring the general provisioning of the metallurgical industry in Area 4, the overall assemblage displays characteristics that remain throughout much of the occupation in this area and point to an organization that is distinctly multi-craft in nature. First and foremost are the quantities of chipped stone debitage, which is composed of obsidian, flint, chert, and, somewhat surprisingly, carnelian.[3] Generally speaking, finished objects made from these materials are extremely rare in the Area 4 assemblage, the major exception being finished and partially finished carnelian beads. In addition there has been a handful of obsidian beads

[3] Given the large quantities of raw carnelian that emerged from Area 4, a provenancing study will likely take place soon. Given that much of the gangue material found in Area 4 consisted of red quartz, it is entirely possible that carnelian source is closely related to that of the copper ores smelted in later periods.


Figure 9-4: AT25211 – A small glass pendant with a small Cu-based loop at the top from the central area of 64.73. Photo Credit – Murat Akar.

recovered, while Alalakh is already well-known for its large obsidian vessels from the Level VII Palace (Healey, 2020; Sparks, 2001, pp. 93–97; Woolley, 1955, p. 293), some of which were excavated in only a partially finished state. Thus, while we can suggest that these materials are being worked here from an early period, we may only guess at the products produced from the others based on limited evidence. Second is the widespread occurrence of glass and faience beads in the area, where most of the beads plotted in Figure 9-3 are one or the other of these materials. As with the metals, none of these materials occur in the preceding phase. Although there is no direct evidence for primary production of the vitrified materials at this stage of the occupation[4], their presence may be taken to suggest that they may have at least been shaped in this area, including the manufacture of metal-glass composites as seen in Figure 9-4. Indeed, one hypothesis for the numerous thin Cu-based shafts that have come out of the excavations is that they may be pieces of forming rods for glass beads or drill bits for stone beads and cylinder seals.[5] Given that this is not a setting where luxury goods such as glass beads would be expected in a consumption context, secondary working (if not production) is the best hypothesis, meaning that in addition to our previously

[4] As will be discussed briefly below, it has been suggested elsewhere that later periods of occupation in Area 4 host facilities for the production of glass (Dardeniz, 2018).
[5] This would be vis-à-vis the work of Gwinnett and Gorelick (1999), showing that simple rods with an abrasive were effective for drilling stone.

mentioned casting and refining, these installations likely also served for the working of vitreous materials.

### *9.2.2 Period 4:*

In period 4 we have material from 64.72 and 64.73 in Area 4 (Figure 9-5) and from 32.53-54 in Area 1 (Figure 9-6). The total assemblage from Area 4 is composed of around 200 objects, roughly evenly split between metal and slag finds (n=96) on the one hand and non-metal finds on the other (n=105). In most respects, this assemblage more or less mirrors that of Period 5, yielding a variety of metal objects dominated by amorphous fragments, a large number of glass and faience beads, and chipped stone flakes and cores. In 32.53-54, we find a total

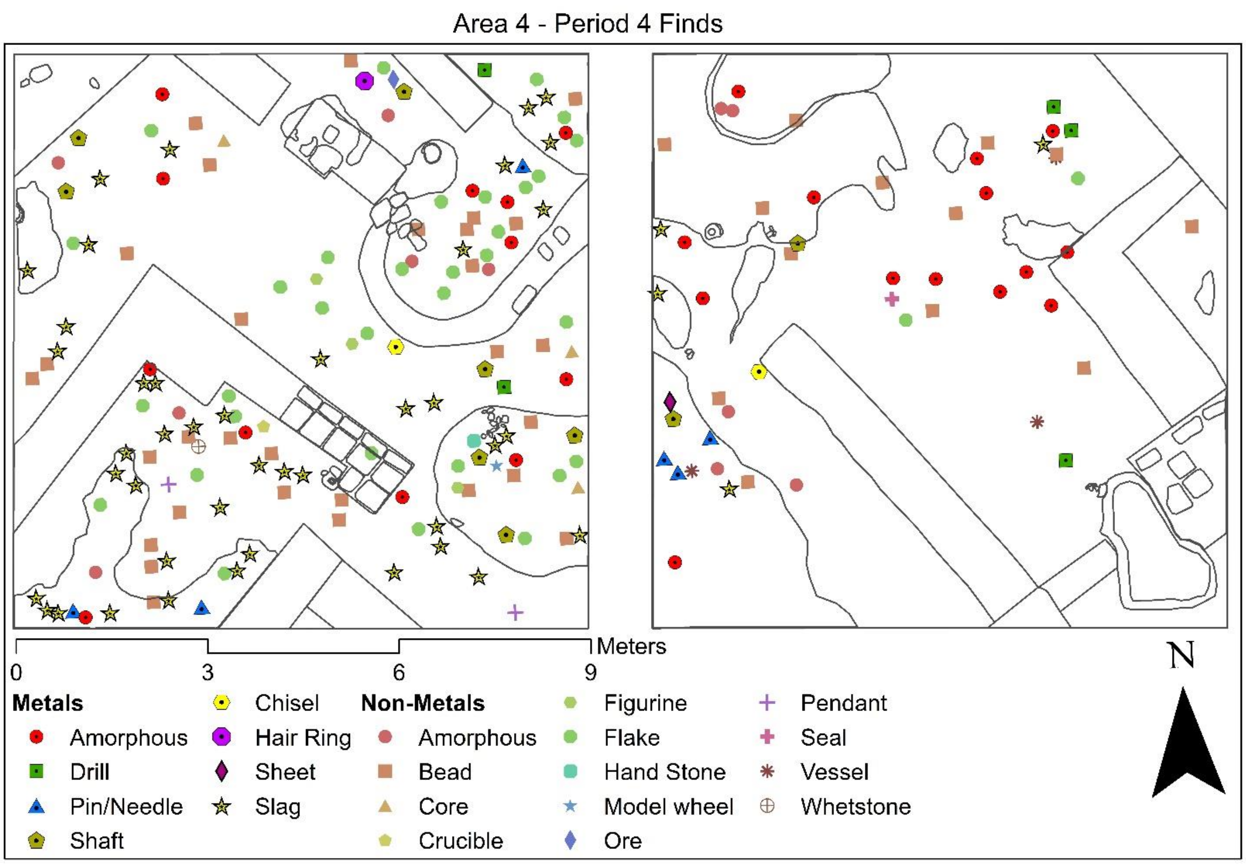



Figure 9-5: Top plan showing locations of metal and non-metal finds for Squares 64.72 and 73, Area 4 – Period 4. © 2020 Alalakh Archives

assemblage of 153 objects, with only 23 of those being metal or slag while the remainder are beads composed primarily of stone and shell, chipped stone flakes, and various basalt hand tools.

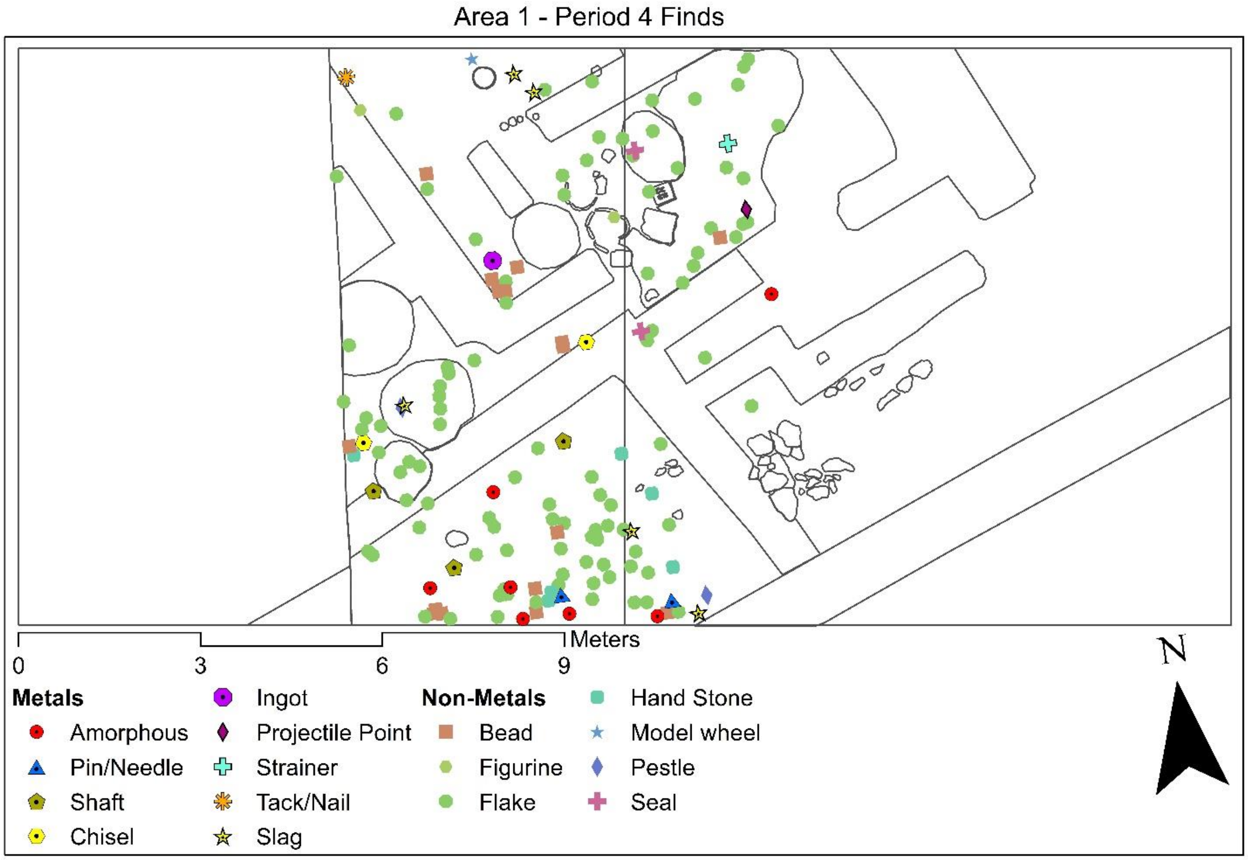



Figure 9-6: Top plan showing distribution of metal and non-metal finds for Square 32.53-54, Area 1 – Period 4. © 2020 Alalakh Archives

Although it is immediately noticeable that a much larger proportion of the Area 4 finds are metal and metal-related compared to 32.53-54, the types of materials represented in each group are largely similar, being dominated by globules of raw and refined copper as well as fragments of heterogeneous smelting product from both areas (AT24677 and AT23469). This is also the first period for which we have bronze in the sample assemblage, with one example from each area, both being high-tin bronzes. While the example from Area 1 (AT24677) was fully corroded and had to be identified based on relict microstructure, the fragment from Area 4

(AT25650) was an amorphous lump with as-cast microstructure. Based on trace element and LI data, this would be an early example of a potential speiss-related bronze. Similarly, ingot AT24079 falls into a class of copper with an unusually high (~0.5 wt.%) Sn content, unfortunately LI values could not be determined from this sample. This could be due to a relation with the speiss-bronzes, but it is more likely an example of mixed metal.

When considered as an overall assemblage, the types of materials and artifacts seen in the palace versus the lower mound are strikingly similar, with a few notable exceptions. First, the Area 1 metal assemblage shows a greater assortment of material than Area 4, reflecting the usual pins, shafts, and amorphous fragments, but also yielding an ingot, arrowhead, tack, and a kohl stick.[6] In terms of non-metal finds, both assemblages boast significant quantities of chipped stone debitage and beads, however, in Area 1 the latter tends to be composed of shell while in Area 4 there is a continued dominance of vitreous products. While a first instinct might be to suggest that the palace workshops lacked the expertise and equipment for handling such material, recent excavations suggest a another, more specialized, area of the palace that may have managed this work. Overall, the main distinction appears to be one primarily of intensity. If there is a vitreous materials workshop in the palace held distinct from this smaller mixed atelier, that would imply a stricter, more specialized organizational structure than that seen in the lower mound, which is also hinted at by later phases in square 42.10.

From a localized perspective, the finds in Area 4 are more broadly distributed than in the preceding period, with less indication of specific pyrotechnical installations. While there were

[6] There is, of course, nothing that demands that these objects were produced in this locale. Given that this does appear to be a secure production context, however, their being somehow related to the activities practiced here should be seen as reasonable.

two located in 64.72, none were excavated in 64.73. Nevertheless, the massive quantities of ash found in both trenches and the lack of evidence for burning of the structures themselves is telling of pyrotechnical activity on a significant scale. Given that much crucible-based metallurgy can be conducted without leaving substantial material evidence aside from ash and pottery, this does not pose a problem to the current interpretation.

In Area 1 (Figure 9-6) a similar situation prevails where most of the metal-related finds were excavated away from the two extant pyrotechnical features, but with most of the area being accompanied by significant amounts of ash. The problem here is that this structure shows evidence of destruction by fire associated with the more general destruction of the Level IV Palace and the context of AT24079 itself suggests that some of the metals fell from a second floor. What we may have here, then, is an even more limited-scale workshop, with some of the finds being objects and raw material stored on the second floor that fell during the burning of the building. The amorphous fragments of raw copper and HSP, all being Taurid sourced material associated with the Area 4 Workshop, could then be interpreted as material that had been collected as tax from those individuals and was being stored in a second-floor depot. This would explain the presence of this primary material while also allowing us to account for the vanishingly small quantities of slag recovered from this context when compared to Area 4.

### *9.2.3 Period 3:*

Period 3 represents the peak of metallurgical activity in the areas studied, yielding the largest assemblages spread across several subphases. In Area 4 (Figure 9-9), these subphases follow a similar vein of development, comprising a coherent compound that represents continuity of activity with Periods 5 and 4. In Area 1, there is evidence from trenches 42.29 and 32.53-54. The former is a marginal area of the upper-mound settlement that is occupied primarily by a dump through Period 3, yielding debris from a wide range of activities from metalworking to butchering. 32.53-54, meanwhile, goes through two episodes of destruction and rebuilding. Throughout these sequences, it appears that the overall production-related assemblage remains relatively consistent with minor fluctuations. For comparison, we may also look at specific aspects of the Period 3 occupation of 42.10. Although excavation of these earlier levels took place too late for inclusion in the analytical phase of this project, several artifacts are instructive for our purposes.

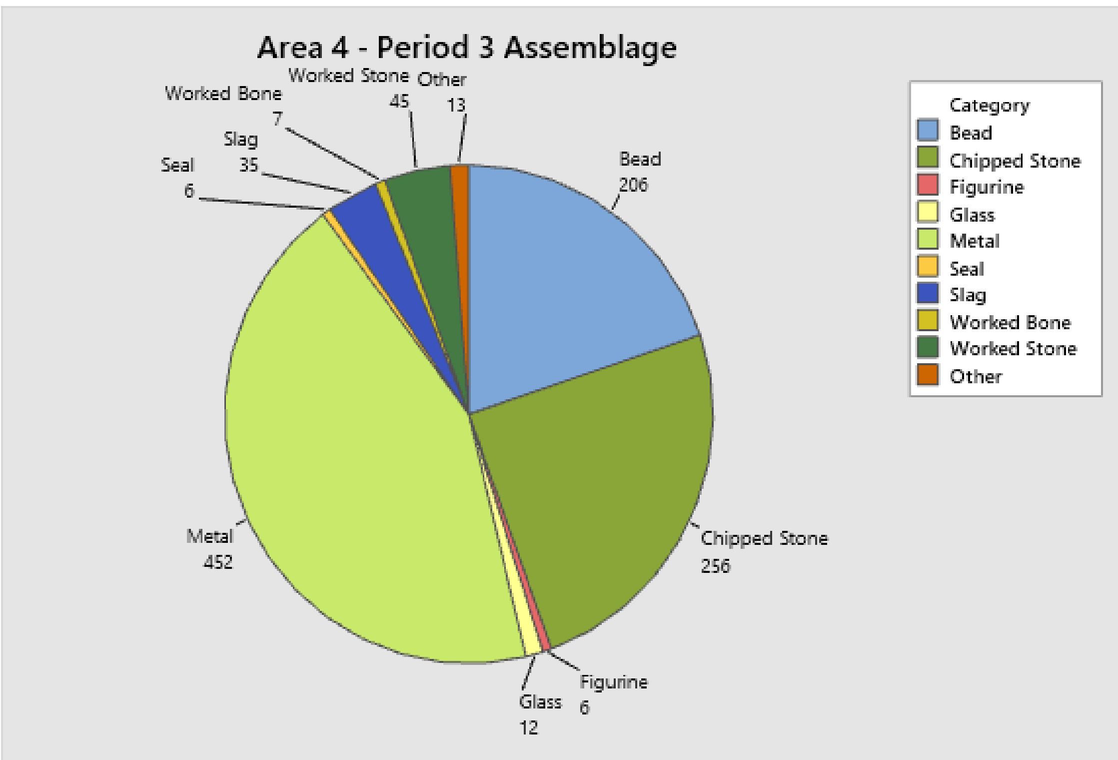



Figure 9-7: Assemblage summary for the active levels of Area 4 – Period 3.

In Area 4, for all trenches except for 64.73 and 64.94, Period 3 is spread across two sub-phases known as 3a and 3b. For 64.73, following my proposed phasing (see; chapter 3), the active portions of Period 3 cover local phases 3a2, 3a3, and 3b[7]. In 64.94, Period 3 is represented by a single phase that is comparatively long-lived. Because these sub-phases represent a long phase of continuous activity with minimal changes to the surrounding structure, I have opted not to sub-divide the assemblage for the sake of discussion.[8]

The Period 3 assemblage for Area 4 (Figure 9-7) consists of a total of around 1,038 small finds. Of these, 381 stemmed from a street context in 64.82, which yielded enormous quantities of debris of all types, but with a general emphasis on metallurgical material. A further 231 objects were recovered from workshop-related contexts in 64.82, while 205 originated from 64.72, 136 from 64.73, and a mere 58 from 64.83, and 34 from 64.94.[9] Within this overall collection, 452 are listed as metal in excavation records[10], while 35 are listed as slag. A caveat does exist in that some of the pieces listed as slag have been suggested to be glass slag rather than metal slag (Gonca Dardeniz 2012, Personal Communication). Finally, of the metals, 199 are derived from secure contexts within the workshop as opposed to 237 from the street[11], while all the objects identified as slag originated from various loci around the compound, but with most originating from 64.72 and 73.

The remaining material from Area 4 consists of 221 beads of glass, faience, and stone – with a special emphasis on carnelian, 268 pieces of chipped stone debitage – much of which was

[7] That is, 3b and 4a according to the usual phasing.
[8] A top plan for phase 3a1 and its associated finds can be seen in appendix 2.
[9] A child burial from 64.94 Phase 3 yielded hundreds of beads and other goods not included here.
[10] While objects listed as metal in the original field notebooks have proved to be invariably related to some metallurgical process, many of the amorphous fragments have proven to be smelting slag, crucible slag, or heterogeneous smelting product.
[11] Note that the total number of metal finds for Area 4 Period 3, 452, comprises approximately 21% of the total metal assemblage collected during the Yener campaign at Alalakh, which amounts to roughly 2106 objects.

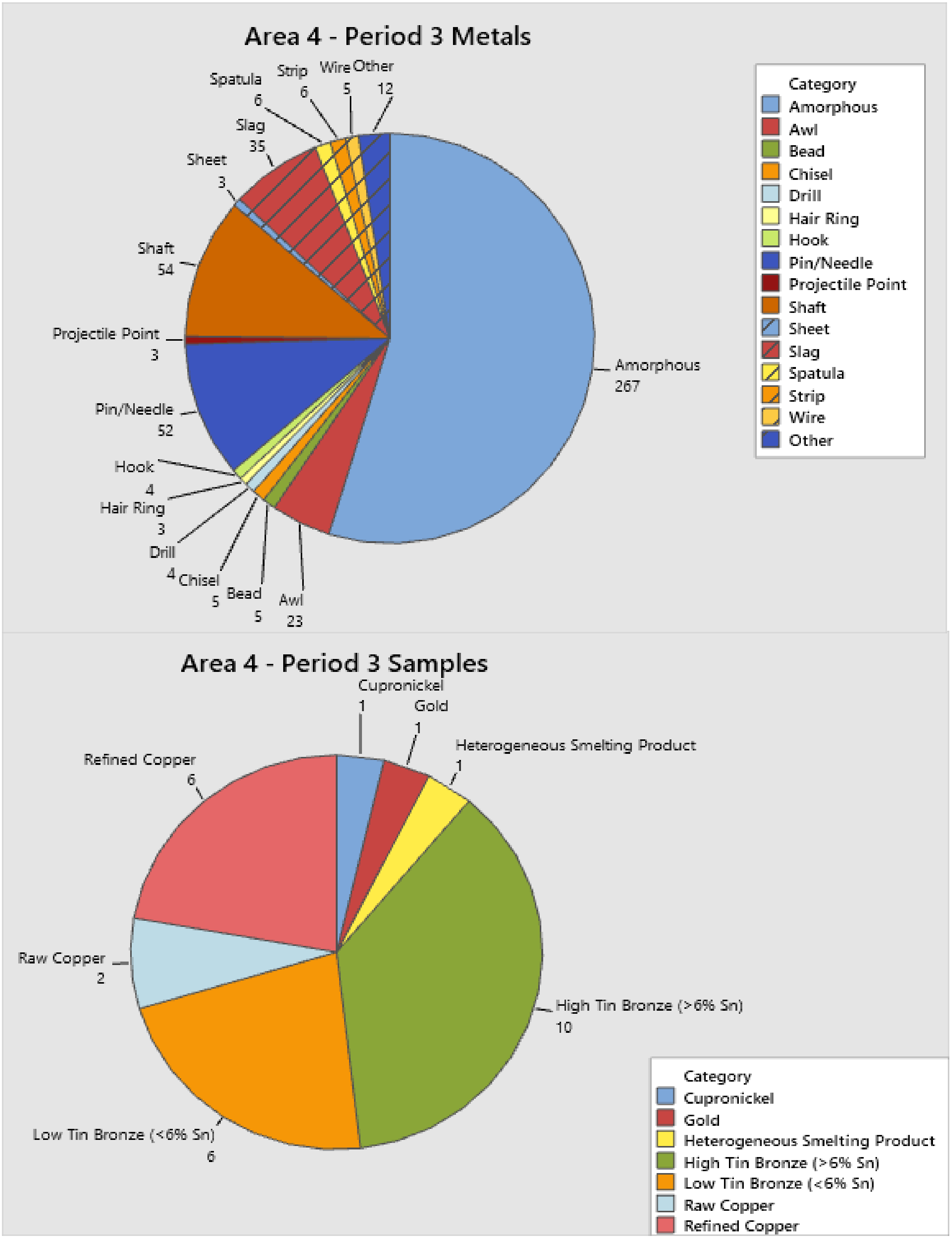



Figure 9-8: General summary of the metal assemblage for Area 4 – Period 3 and the associated samples therefrom.

also carnelian, and an assortment of bead blanks, several spindle whorls, stone tools and other materials. What is notable from the perspective of the gangue material found included into multiple samples (see; chapters 5 and 6) is that the central courtyard of the compound began to yield large quantities of fist-size chunks of red quartz, in line with the high iron quartz identified during SEM analysis that contained various ore inclusions. Though none of this material has yet been analyzed, the connection bears mentioning in potential support of the SEM data and the hypothesis of ore processing in the compound. Finally, AT8039, a fragment of polymetallic ore mentioned in chapter 6, was excavated in local phase 3b of 64.72. In short, although Period 3 ultimately represents continuity in practice with Period 4, several noteworthy changes take place including a substantial increase in scale, in line with the establishment of a more coherent, organized structure.

From the perspective of metals being handled in Area 4 (Figure 9-8), tin-bronze becomes the predominant material, with Fe-rich raw copper and refined copper becoming less prominent. In addition, cupronickel makes its first appearance in the assemblage along with limited quantities of gold. Among the bronzes, in terms of the PCA results from chapter 7 we continue to see speiss-related bronzes, however, a greater proportion trends closer to the main body of raw and refined copper samples, suggesting that they are the product of alloying with a purer tin-rich material. In either case, what these developments suggest is an overall broadening of material access for the Area 4 workshop.

Alongside this broadening, the slag assemblage also shows several modest developments. The first of these is the first appearance of crucible slags containing high-Sn prills with little to no trace elements, which is the primary evidence for alloying of tin metal or cassiterite with copper to produce bronze. Though it is impossible to definitively exclude processes based on crucible slags (Rademakers and Rehren, 2015), the examples here have not yielded much indication that cassiterite was the alloying agent, suggesting the use of tin metal. If this is the case, it would support a hypothesis that during the LBI-LBIIa transition, larger quantities of tin metal were making it into the city. Regarding heterogeneous smelting products, we continue to see the generation of fayalitic slag in association with metal containing large amounts of metallic iron. However, in 64.94, next to one of the pyrotechnical installations, Period 3 also yielded a fragment of matte (AT18636) with adhered high-Mg and Al slag, which is the first occurrence of both this slag type as well as of matte in a massive form, as opposed to small slag-entrapped inclusions. Taken in conjunction with the finds of gangue material (ilmenite and ilmenomagnetite) from AT8040 and chromite entrapped in slag from AT8019, this signals the earliest secure indications for on-site copper smelting in first phase of Period 3.

Among the objects being produced and used (Figure 9-8), it is immediately apparent that we are no longer dealing with the primarily tool-based assemblages seen in Periods 5 and 4, with their relatively greater emphasis on shafts, drills, and chisels. Instead, though these categories still comprise a majority, there are overall greater quantities of decorative and presumably luxury items ranging from apparent vessel fragments (i.e. AT8002) to potential pieces of metal inlay (see; chapter 6 regarding AT8048) to fine wire (AT8915). Aside from this expanded repertoire of objects, we also see new techniques being employed such as the use of high Sn-solder (AT21332) (Craddock, 1984), the application of which was likely similar to the tinning method for AT4113. In view of these developments, Period 3 seems to represent a time where the purview of this workshop has expanded to serve a potentially broader clientele with a wider range of goods. Where earlier metal use appears to have been geared toward supporting the manufacture of other objects and small tools, there is now evidence for the production of metal products for their own sake, as well as composite artifacts such as the already known shell and glass examples, but also including probable claddings for furniture and other objects (Yener, 2014, 2007).

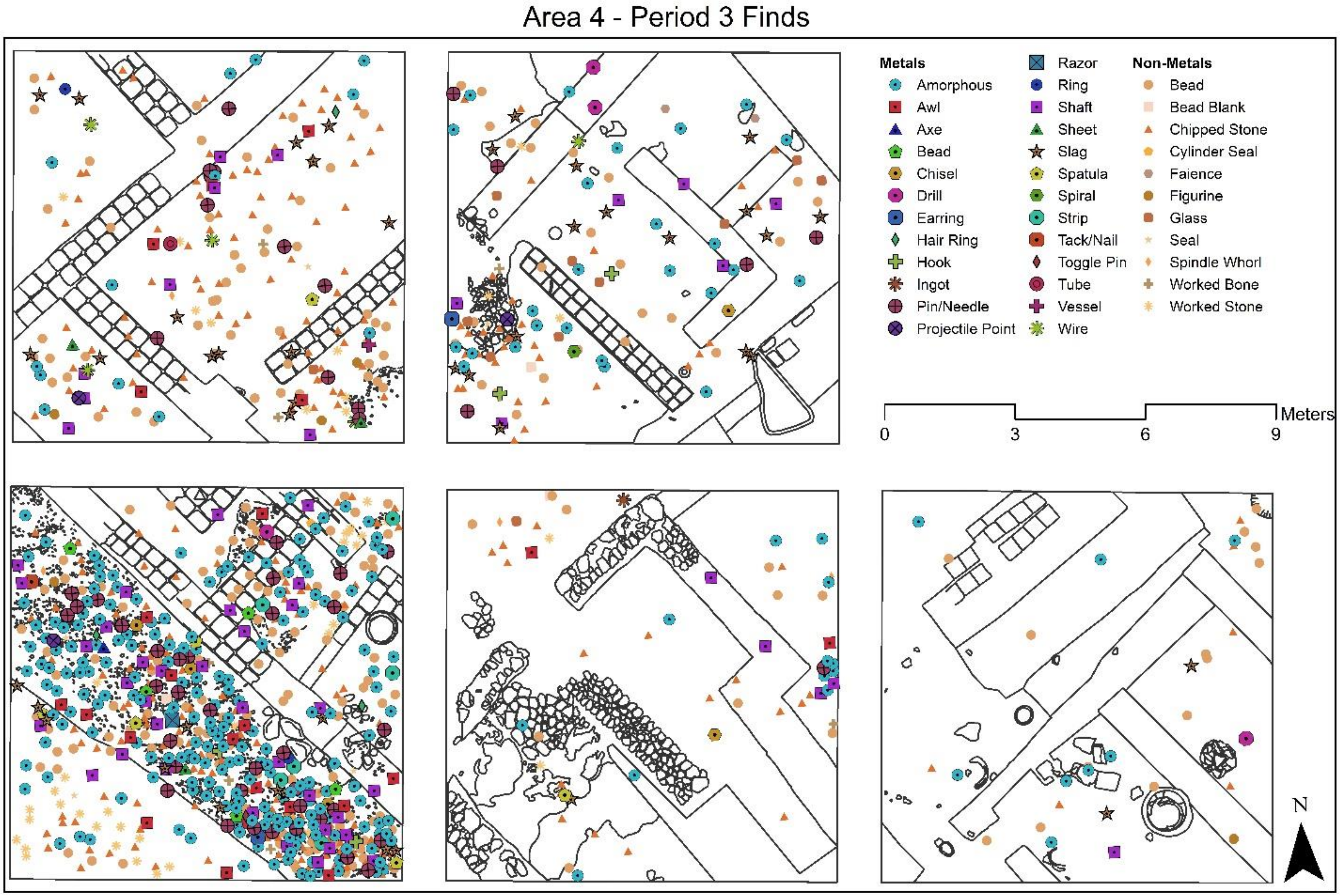



Figure 9-9: Plan showing the distribution of finds for 64.72, 73, 82, 83, and 94, Area 4 – Period 3. © 2020 Alalakh Archives

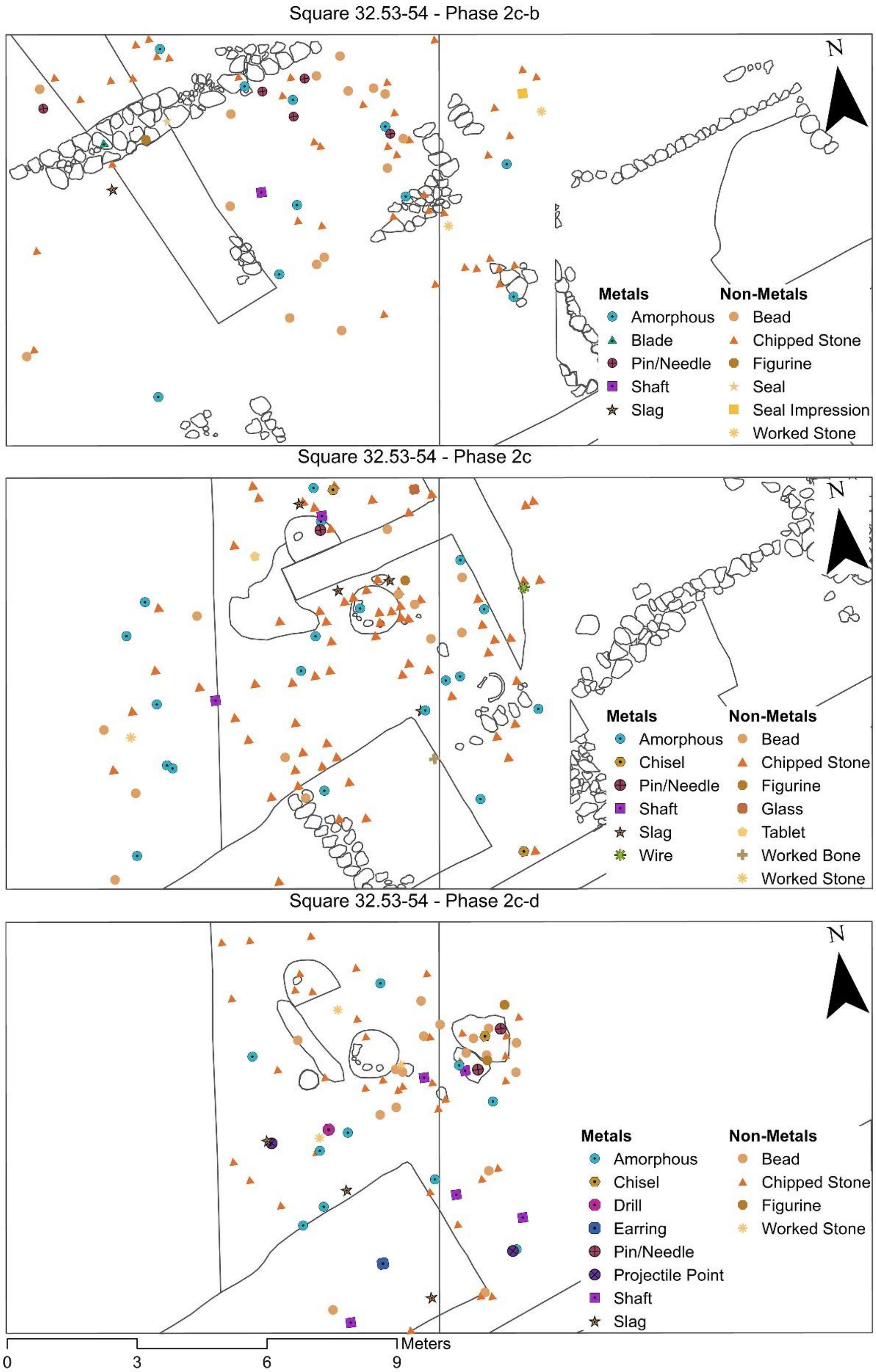



Figure 9-10: Top plans showing distribution of artifacts across the Period 3 sub-phases of Square 32.53-54. © 2020 Alalakh Archives

In square 32.53-54, we are confronted with a sitution where, following the major Period 4 (Phase 2d) destruction of the palace, two further episodes of destruction and construction take place (Figure 9-10). Despite these distruptions resulting in the formation of noticeable transitional phases, the degree of overall continuity seen in the production-related assemblage up to the end of Period 3 is somewhat surprising, when local phase 2b yields very little in the way of finds at all, apparently mirroring what occurs at the same time in Area 4. Looking at Figure 9-11, it is immediately apparent that the distribution of metals in the assemblage remains relatively consistent over time, with the primary fluctuation being in the quantities of chipped stone debitage recovered.

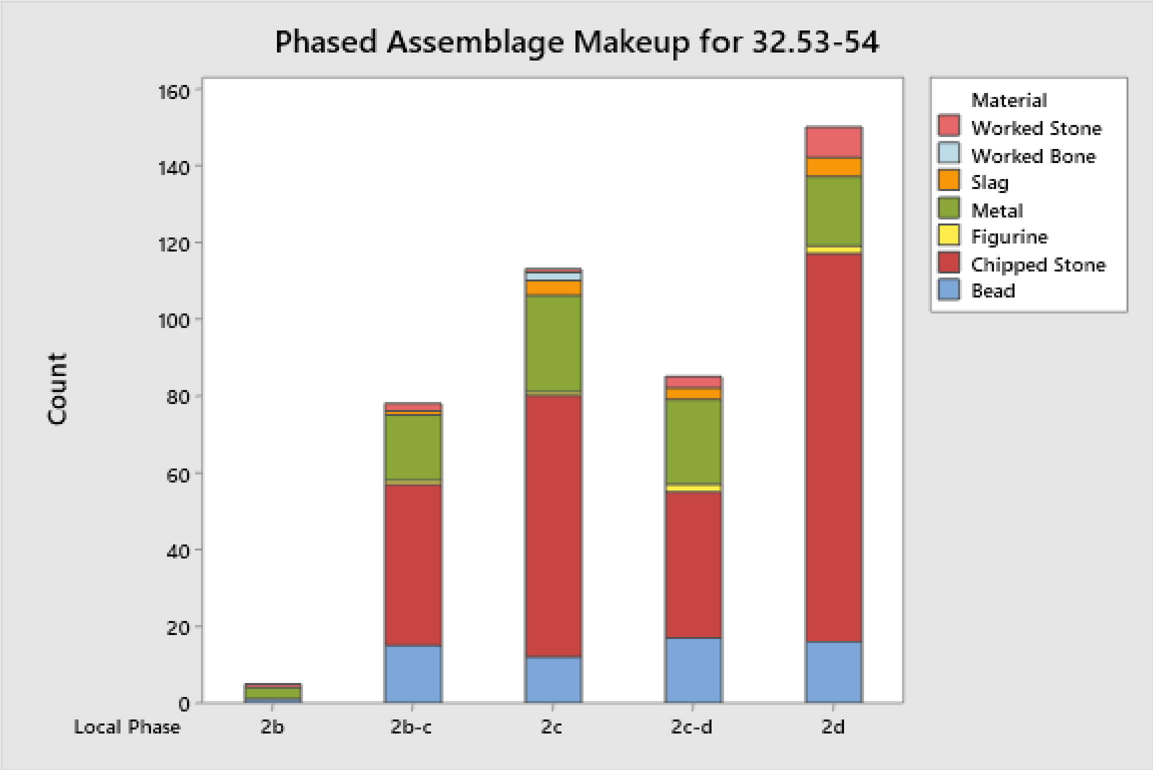



Figure 9-11: Phased distribution of finds within the assemblage of 32.53-54.

Nevertheless, it is important to consider that, from a contextual standpoint, transitional phases 2d-c and 2c-b basically represent periods when this area was essentially devoid of standing architecture. A couple of smaller pyrotechnical installations were present, along with significant quantities of ash and heavily worn pottery, but little else. Among other things, this suggests that low-level crafting activity continued in the same spot regardless of the architectural situation, sometimes going long periods exposed to the elements. For such a context the term "palace workshop" seems grandiose – the palace appears to have been perfectly happy to let at least some of its artisans work in an abandoned lot. On the other hand, a further implication here is the tendency, as seen elsewhere on the site, for long-term continuity in the usage of space (Yener, 2015b).

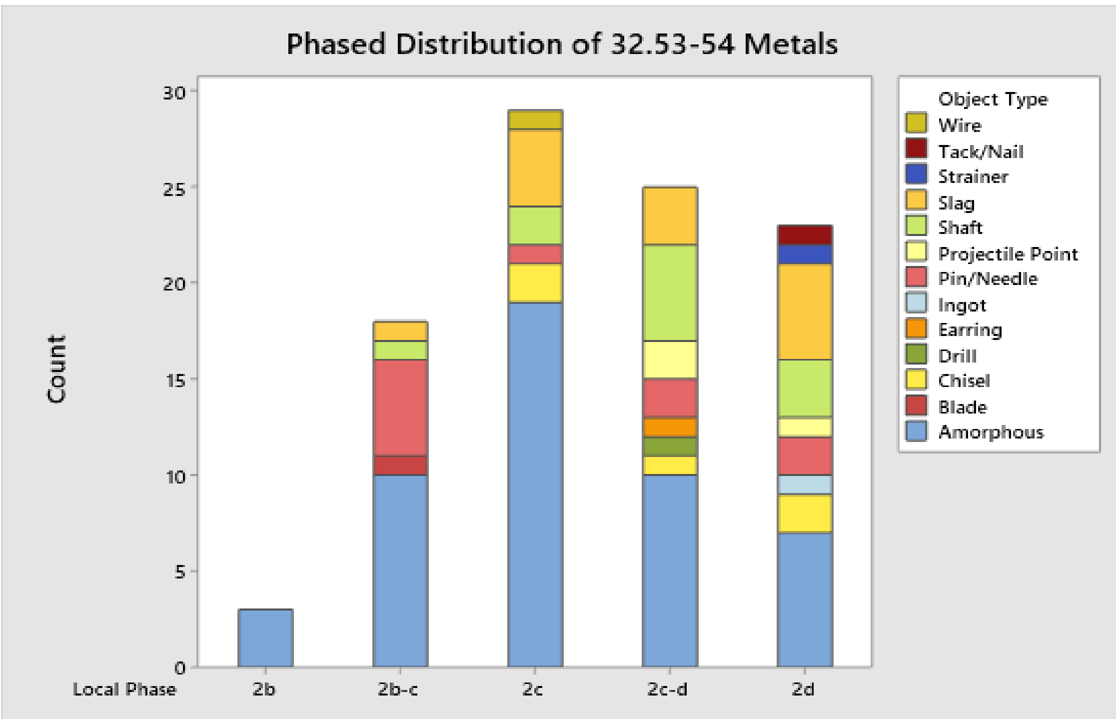



Figure 9-12: Metal objects presented as a function of phase.

If we then look at the phased distribution of metals from the 32.53-54 assemblage (Figure 9-12), we may first note that the overall number when compared to Area 4 is significantly lower, even when considered on a per-square basis. At first glance it appears that at a time when the Area 4 workshop is expanding its repertoire and gaining access to new materials, this small palace workshop is working with the same range of material that it had been dealing with prior to the Period 4 destruction. Although the number of samples taken for Period 3 from this square (n=5) is too small to allow for much secure comment, it is worth noting that the period 2b-c transitional phase yielded the small silver-plated votive chisel mentioned in chapter 5. As such, we may venture that the assemblage here is not as blandly utilitarian as it first appears. Unfortunately, because all of the other associated Period 3 samples were completely corroded, it is not possible to say much beyond the observation that high-tin bronze and raw copper are also present as part of the amorphous assemblage, suggesting further continuity with earlier tradition.

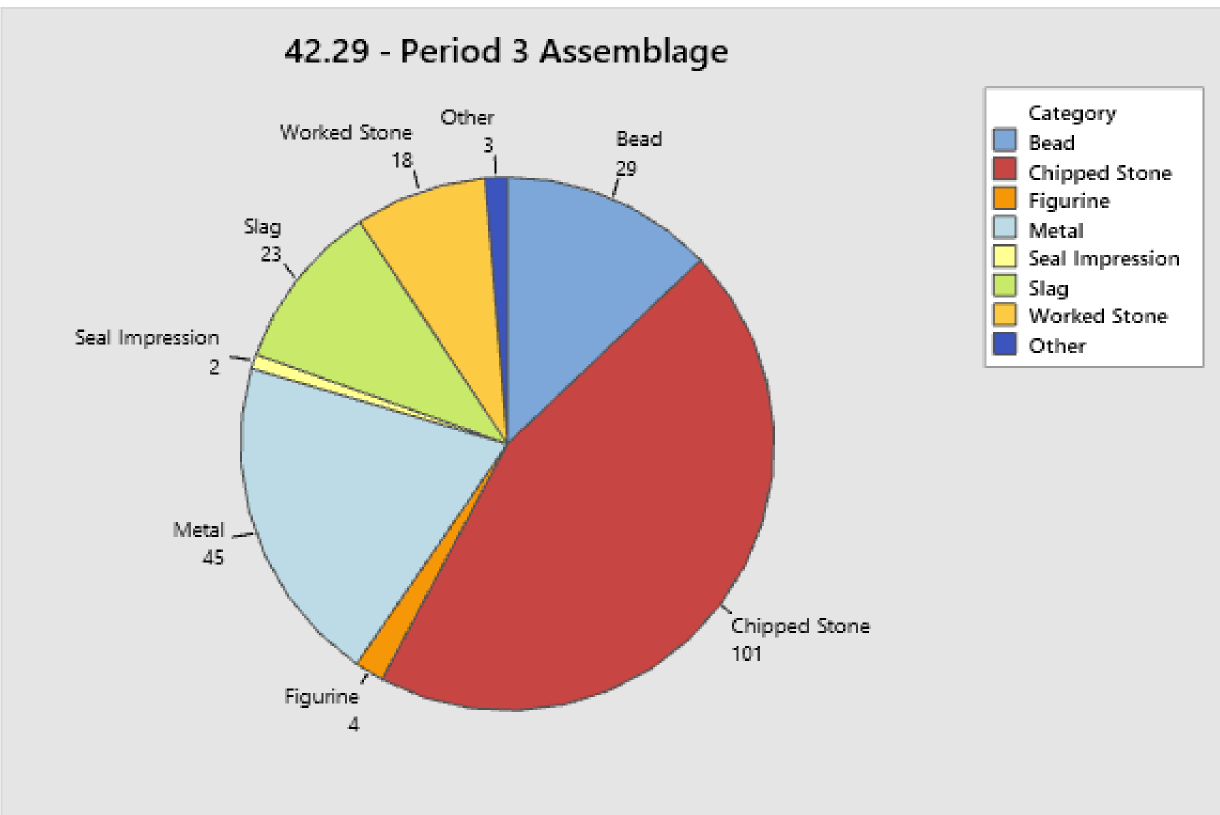



Figure 9-13: Summary of the 42.29 – Period 3 assemblage.

For square 42.29, the small sample size (n=2) once again presents problems for interpretation, in as far as our two fragments of heterogeneous smelting product can hardly be used to extrapolate from the broader assemblage given its size and diversity. In addition, the lack of coherent architecture further complicates matters by depriving us of a bounded stage for the activity under discussion. Nevertheless, the recovered assemblage is so extensive and yet derives from such a small area that its consideration is important. Further, its proximity to square 42.10 and the assemblage derived from the contemporary phases there provide for several interesting observations related to organization of production. In Figure 9-13, the size of the Period 3 assemblage – 84.4% (n=190) of which derives from local phase 4, the phase 3 portion (n=35) being primarily chipped stone – is immediately apparent.

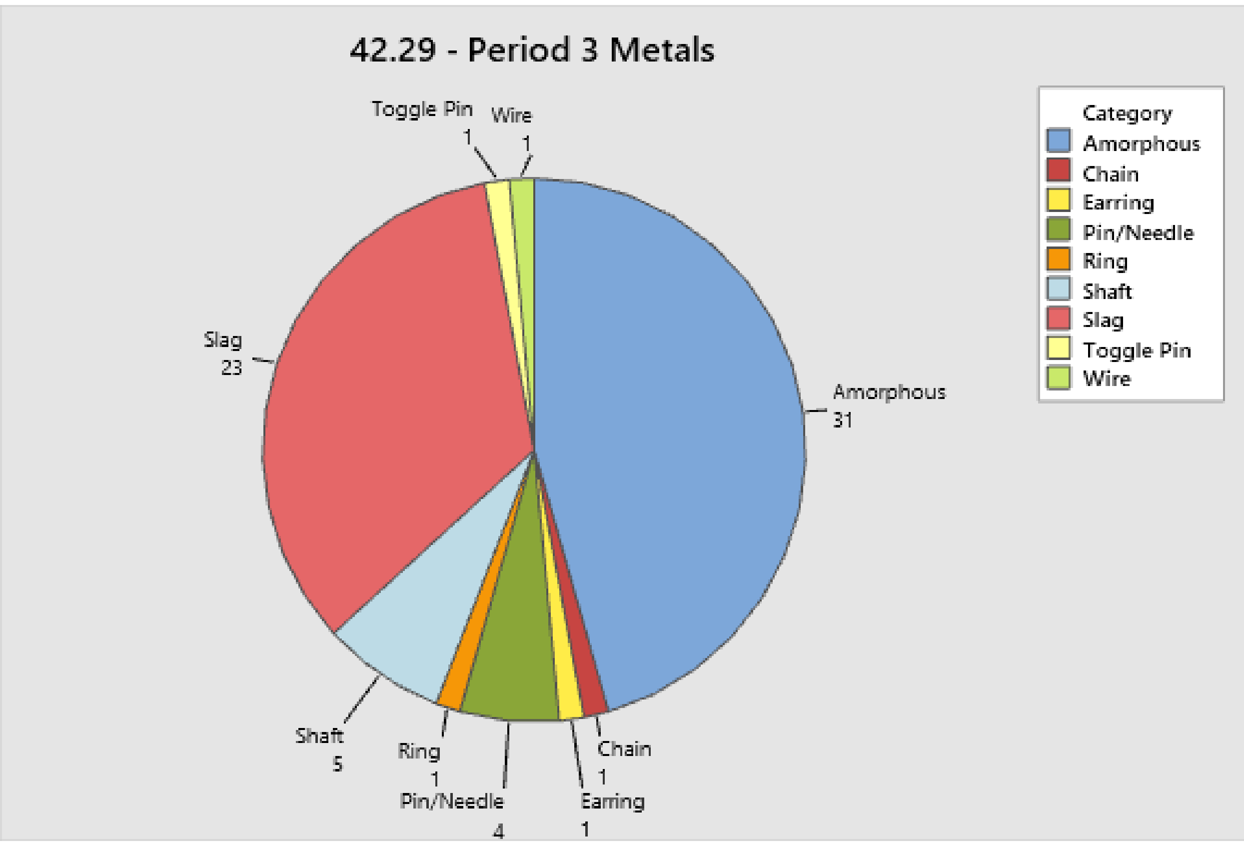



Figure 9-14: Summary of metal finds from 42.29 – Period 3

Despite most of the assemblage being comprised of chipped stone debitage, the next largest portion is that related to metallurgical activity. If we break this portion down further

(Figure 9-14), we see a familiar distribution in terms of tools and a more limited number of decorative items, while the majority is comprised of amorphous fragments. As seen in other areas, the amorphous fragments sampled from this area also turned out to be heterogeneous smelting product with adhered fayalitic slag. Beyond this, composite objects such as shell beads strung along a length of wire were also derived from this context (Figure 9-15), illustrating unique luxury items that tend to be hidden in the process of typologizing. When taken in combination with the observation that much of the recovered pottery consists of fine imports while the bones include those of large animals such as elephants, an association with higher-status elements of the palatial apparatus seems likely. Without putting too much weight on this speculation, I would continue to support the excavation team's hypothesis that this dump is directly connected to activity in square 42.10. If this is the case, then it would suggest that there are significantly more active workshops than 32.53-54 within the palace and temple precinct that handle a more substantial range of material. Indeed, this is what is hinted at by the Period 3 phases of 42.10.


Figure 9-15: AT18756, from 42.29 Period 3. Two shell beads strung along a length of copper wire. Photo Credit: Murat Akar. © 2020 Alalakh Archives

The Period 3 metal assemblage for 42.10 is relatively small, being comprised of only 20 objects. Of these, two are lead while the remainder are Cu-based, 5 of them being amorphous, while the others are tools, rings, strainers, and the odd arrowhead. Of the amorphous samples, it was noted that the outer corrosion layer of one included a substantial amount of iron corrosion and was generally highly magnetic, suggesting that it was either raw copper or heterogeneous smelting product. Much of this is relatively unremarkable but for two additional finds of casting molds. One of these is a small clay mold for casting rings (Figure 9-16), while the other is a large multi-faceted stone mold with signs of extensive use including the relocation and concentration of mica inclusions toward the outer edges of the casting cavities (Figure 9-17).


Figure 9-16: AT26408 – A small clay mold for casting rings. Photo Credit – Murat Akar. © 2020 Alalakh Archives

Up to this point, most molds that have been found were small clay examples for the casting of either small trinkets or small blades, giving us little clue on the more materially demanding aspects of the industry. With AT26316, we appear to have a mold for the casting of blanks for small vessels – the disc on the reverse – and blanks for slightly larger blades or some

Figure 9-17: AT26316 – Upper and lower surfaces of large multi-faceted mold. Photo Credit: Murat Akar. © 2020 Alalakh Archives

other tool, represented by the tapered cavity on the side. Following the excavation of a further fragment, we can now suggest that the tanged cavity on the obverse face was for the casting of a relatively large lugged axe (fig. 19). Though its exact dimensions are up to speculation, its thickness suggests a hefty example of a form well-known in Anatolia (Maxwell-Hyslop, 1953, p. 84).

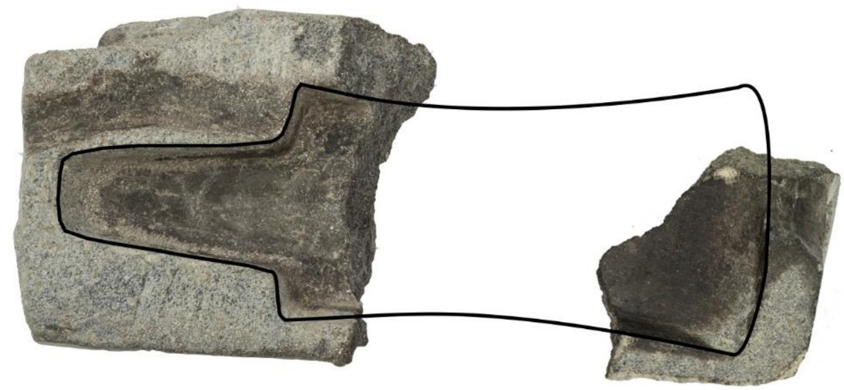


Figure 9-18: Proposed reconstruction of mold fragments AT26316 and AT26538. Photo Credit: Murat Akar. Composite created by the author. © 2020 Alalakh Archives

Keeping in mind that this is only an individual example, the discovery of high-quality stone molds is enough of a rarity to bear mention, indicating the presence of a professional class of metalworker capable of handling large volumes of molten material and in need of a durable kit. Given the differences in character between the 42.10 context and those of 42.29 and 32.53-54, this hints at the possibility that more specialized palace workshops were also present. For example, the other Area 1 workspaces may have been associated with material preparation – refining, manufacture of small objects, working of other raw materials – while 42.10 or a closely associated space would have handled larger projects such as the production of large tools, weapons, and vessels.

*9.2.4 Period 2:*

Period 2 presents some of the most exciting material in the analytical assemblage within one of the most disappointing and anti-climactic archeological contexts possible. In Area 1, the small workshop of 32.53-54 is overbuilt with the gargantuan edifice of the Northern Fortress while 42.29 has a limited occupation with no indications of production. 42.10 yielded almost nothing of note. In Area 4, the once-bustling ateliers that wound down toward the end of Period 3 were overlain by the Southern Fortress. From here, there are two likely narratives. The first, already alluded to in chapter 7, is that this fortress is accompanied by minor scale metallurgical production in an open space to its southeast, with the most direct evidence yet for speiss-related bronze production. That there are a couple pyrotechnical features in evidence helps this assertion somewhat while the previous use of an abandoned lot as a workshop in Area 1 shows that this is not an unusual setting. Nevertheless, the remaining assemblage of Period 2 in Area 4 is so limited and contains so little production debris that a second option is worth considering.

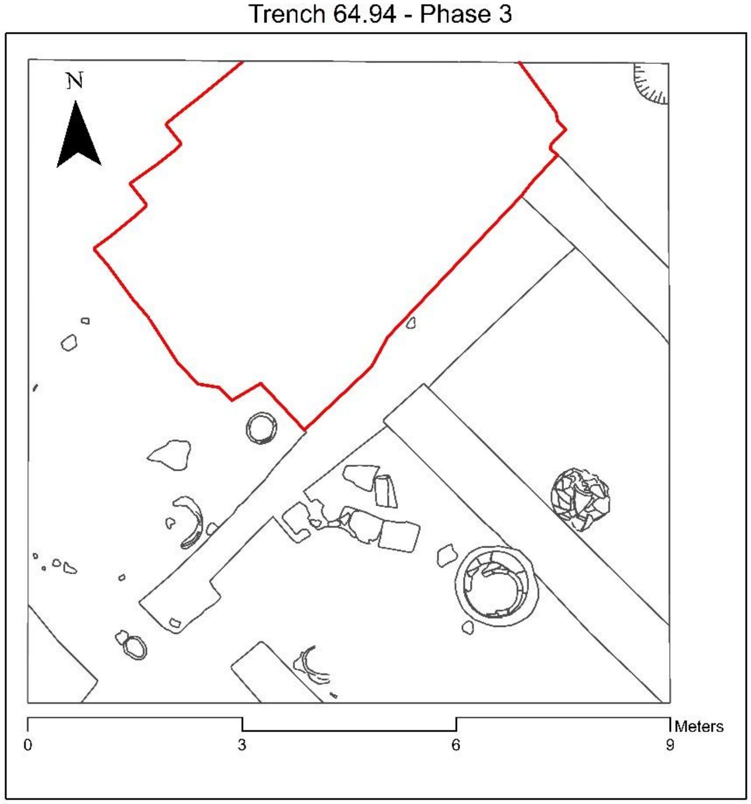


Figure 9-19: Top plan of square 64.94 indicating Period 2 foundation trenching in red. © 2020 Alalakh Archives

During the construction of the fortress, the builders generally attempted to build atop the walls of the Period 3 compound[12] as foundations and, where this was not possible, they dug foundation trenches that they subsequently filled with mudbrick. This trenching activity was limited only to trenches 64.73 and 64.94 in the indicated areas of Figure 9-19. For 64.94, this trenching cut into another courtyard

[12] This could also be why 64.73 Phase 3a1 is only shown in that square, it may have been obliterated in other squares by the construction of the fortress.

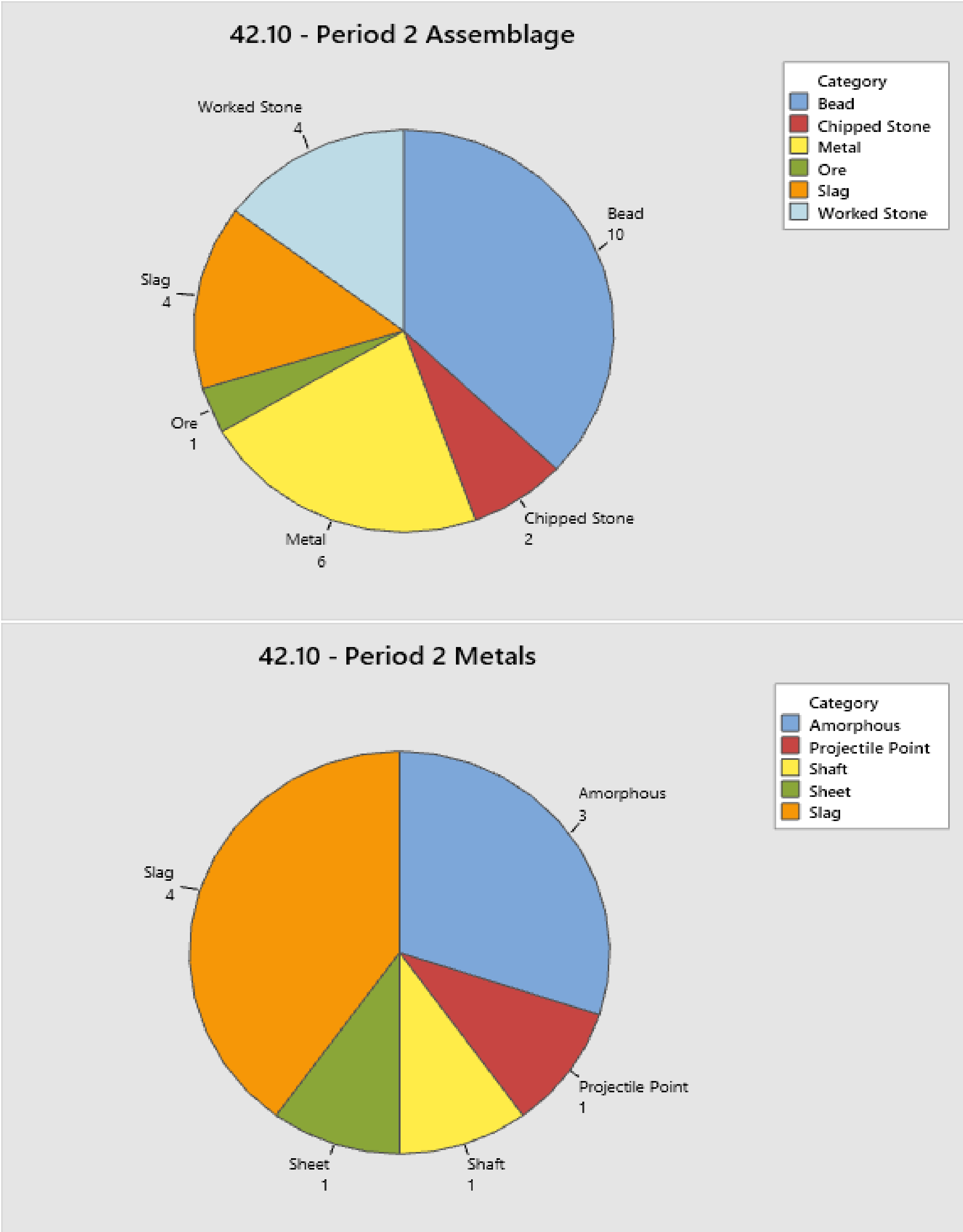



Figure 9-20: Summary charts of the 42.10 Period 2 assemblage.

of the Period 3 compound, immediately adjacent to several furnaces. I would hypothesize here that, in the course of cutting this trench, the builders turned up debris from the Period 3 activity and redeposited it in the open area immediately southeast of the fortress. This scenario has the benefit of accounting for the stratigraphic gap of ~12cm between the tops of the Period 3 walls in 64.94 and the metallurgical debris excavated in the Period 2 levels of the square while avoiding the need for such an awkward hiatus in production of essentially the same type of material. According to the current phasing, the narrative is such that, after the Period 3 cessation of activity in Area 4 and the construction of the Southern Fortress, craftsmen are either brought back under Hittite direction or return on their own to conduct limited production of bronze. Meanwhile, the alternative explanation outlined above would suggest that the final period of primary metallurgical production in Area 4 was Period 3 with some possible small-scale secondary working in Period 2 indicated by a few finds from within the fortress itself. Realistically, this second interpretation does not change the preceding discussion in any substantial way, merely indicating a longer or shorter duration for the technological style I have been tracing up to now.

Because, as noted above, there is no Period 2 assemblage for 32.53-54 and that for 42.29 contains no material relevant to the current discussion, neither will be considered here. However, since 42.10 continues to have relevance for a little longer, the assemblage is summarized in Figure 9-20. As can be seen, it is miniscule and, if it indicates any production activity, it would seem to be vanishingly small in scale.

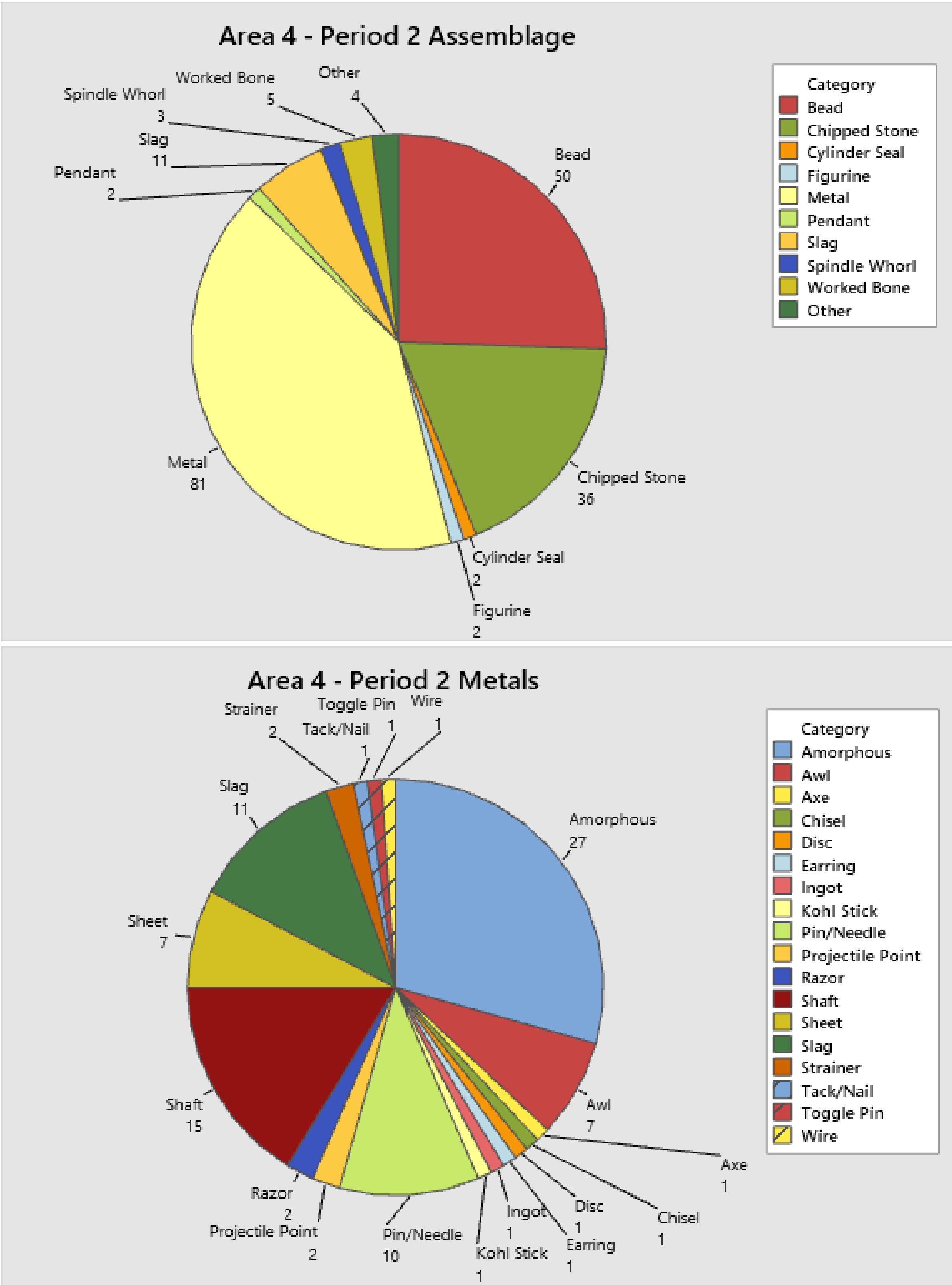



Figure 9-21: Summary charts of Area 4 – Period 2 assemblage.

In Figure 9-21, the Area 4 assemblage continues to host substantial quantities of metal as well as a modest quantity of slag. Although it should be noted that a 5kg collection of slag originating from the outside area southeast of the fortress was taken under a single AT number (AT4109), making this the largest single collection of metallurgical slag recovered from the site. As such, simple counts of artifact numbers can be misleading. Looking at the general metal assemblage, it is more diverse than previous periods, including both personal grooming equipment, weapons, and drinking paraphernalia, marking the substantially different priorities[13] of the new occupants. On the other hand, the LI signature for the Period 2 samples from secure Southern Fortress contexts shows a continued use of south-central Taurid ores for producing these metals. This means that either there were old metals in circulation being reworked, or the previous inhabitants of Area 4 had simply moved elsewhere in the city.

### *9.2.5 Periods 1 and 0:*

Coming now to the terminal occupation of the site, Period 1 – the end of the LBA – and Period 0 – the very beginning of the EIA – are represented only in a limited area of the summit of the mound. 42.10 is, in fact, the only part of the mound where a direct chain of occupation can be traced through this transition period (Montesanto, 2017; Montesanto and Pucci, 2019). Though there are only limited hints of production debris, what little there is suggests continuity with earlier phases, and in particular the continued use of speiss-generating processes.

The general assemblage for Period 1 in 42.10 is substantially expanded from the 27 objects excavated from the Period 2 occupation, being comprised of a similar range of products to that seen in the Period 2 assemblage of Area 4, including personal grooming equipment and

[13] More entertaining?

drinking paraphernalia. In addition, several lead objects were recovered as well as the rather unusual Cu-Ag-Ni object, AT21204, which continues to set this square apart from others in terms of the materials and objects being used. The slag assemblage remains small, but sample AT21470, a fragment of smelting slag undoubtedly deriving from a much larger cake based on its morphology does contain fragments of chromite in line with those examples first seen in Period 3, which marks an element of continuity.

It is unlikely, based on the general context presented, however, that it was produced in the immediate area where it was found, probably making its way there alongside raw material. What is unique about this sample is that it is the only example in the assemblage of a well-consolidated slag that can be reasonably hypothesized to have come from a much larger cake. This itself would imply larger individual smelting events than seen in earlier phases. In this respect, sample AT6393, taken as part of a set of separate investigations from Period 1 levels of square 43.54[14], located 32m southeast of 42.29 and 39m south of 42.10 is of substantial importance, given that it represents the latest piece of evidence for speiss-related bronze production, while also suggesting the association of this material with silver. Unfortunately, these are individual finds, and so their importance is rather tempered by the contexts in which they were found. In an ideal situation, what little we can glean from this period then, is that continued production activity took place within a limited area at the summit of the mound, with 42.10 either hosting or being in proximity to secondary working activities. Meanwhile, toward the edge of this area, primary smelting, relying on technical processes long in practice at the site

[14] A valid question might be why material from this square was not included in the original project design, particularly given how important it has turned out to be. The simple answer is that only Period 1 contexts were ever excavated here, making the temporal extent of the data too short. This being said, in light of present evidence, a future study should be considered.

but typically associated with a much different socio-spatial context continued at an indeterminate scale.

In the initial phase of Period 0[15], there are no longer any standing architectural features in 42.10, with only the possibility of some ruins from local phase 4a. In this rather desolate setting about 10 metal finds and 6 slag fragments were recovered, among a small number of other materials. In general, this type of context would not have been considered of special interest due to the small volume of finds and the presence of only a single pyrotechnical installation. However, during subsequent analysis of AT19597 following its initial publication (Johnson, 2020), the observation of adhered barium-rich iron arsenate gangue which provided an important link between the object, the technical processes of its production, and its immediate context made its inclusion and reinterpretation worthwhile. Given the evidence available from this single object and its context, it is probable that this final phase of activity was short lived – possibly a single episode – and possibly limited to activities linked to the production of precious metals. What is interesting here is that this production was taking place within the ruin of a completely abandoned city, seemingly[16] independent of any remnants of administrative oversight, still utilizing raw materials related to what we had seen in use over the previous two centuries.

## 9.3 Compositional Trends in Space and Time:

Given that the results of GIS spatial statistical analysis suggested the absence of underlying trends in the distribution of artifacts based on process-related compositional criteria, while the simple spatial observation of finds in context could suggest only minor differentiation

[15] Period 0 is composed of three phases, only the earliest of which is considered here as the direct transition between the LBA and EIA.

[16] The old adage about absence of evidence not being evidence of absence still applies, of course.

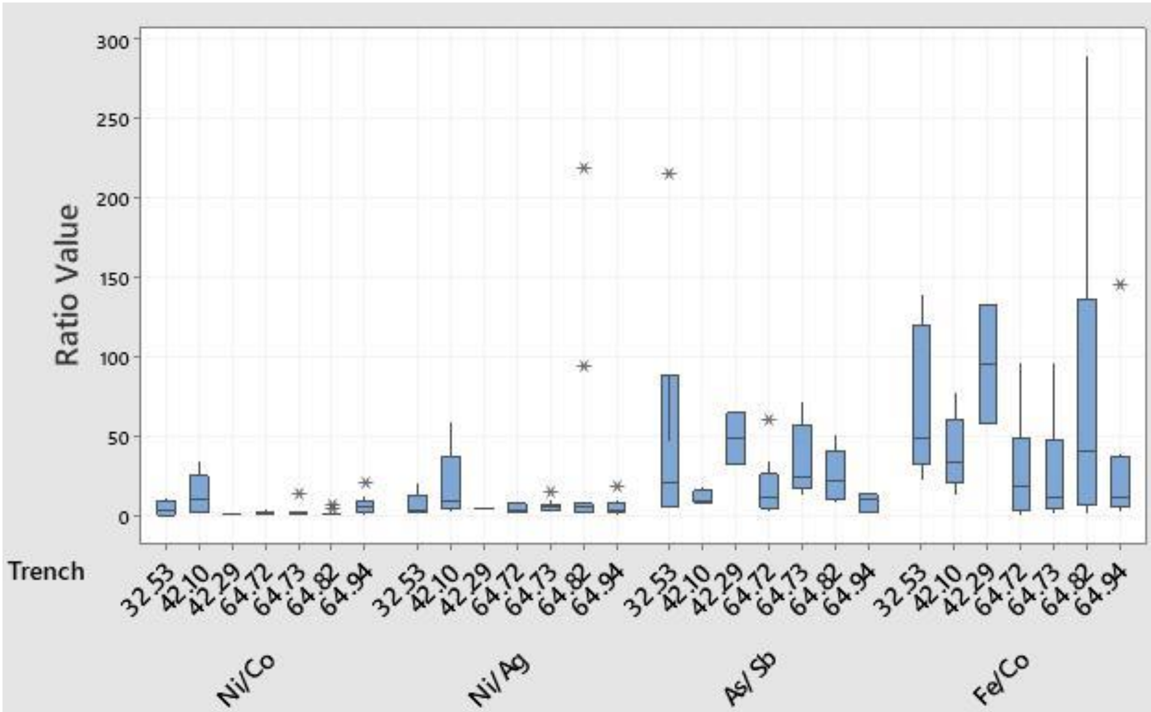



Figure 9-22: Boxplot illustrating range of elemental ratios by square as determined by LA-ICP-MS. Note that in particular for Ni/Co and Ni/Ag, the Area 4 ratios display more consistent values overall, though with more outliers. This may be taken to indicate the common source for much of this metal as well as the presence of outliers related to unpredictability of alloying material. The As/Sb and Fe/Co ratios show a similar pattern, though volatility and oxidation processes for these elements make it less clear cut.

of working spaces, I opted to plot elemental ratios – in particular Ni/Ag, Ni/Co, Fe/Co and As/Sb – in relation to the trenches in which they were found (Figure 9-22). In general, the Cu-based samples subjected to trace element analysis support the patterns identified in the LI data, showing that the Area 4 samples are more internally consistent than Area 1 in terms of provenance-related elements (Ni, Co, Ag) with a few outliers likely related to unpredictable alloying material and the "fresher" nature of the metal, having been subjected to fewer processes that would result in homogenization. It is worth noting that this is in spite of not differentiating between classes of material. In Area 1, there is an overall wider spread of ratios consistent with material sourced from a range of deposits with different characteristics. This is in line with the LI data, fitting with accumulation of metal from various sources in the palace that is gradually

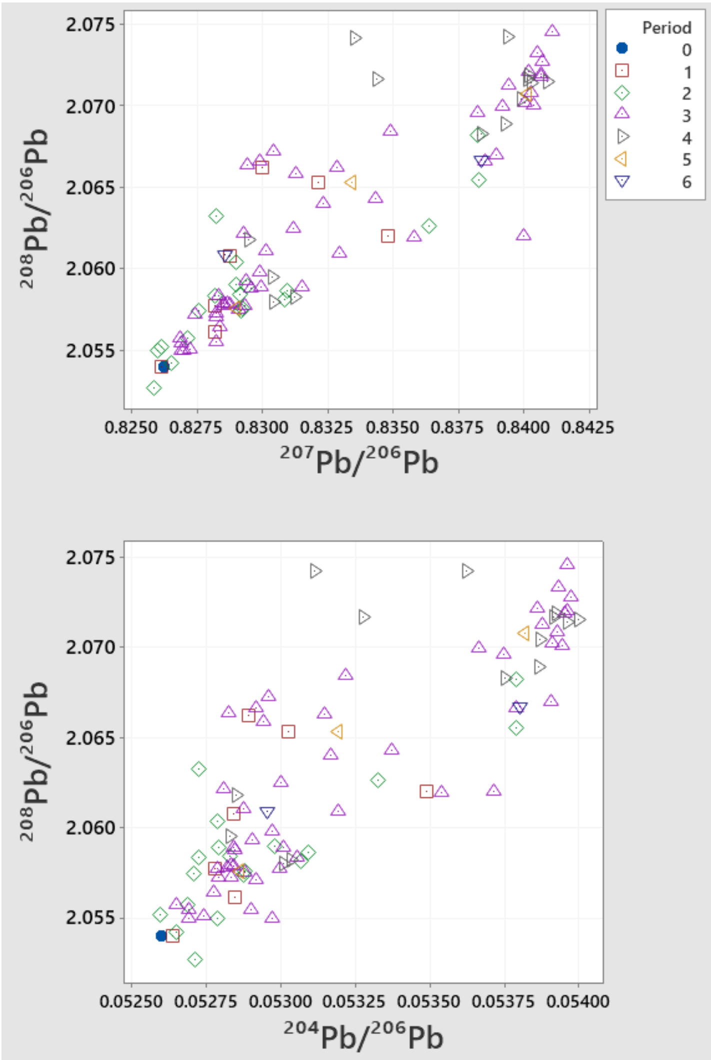



Figure 9-23: Lead isotope plot showing points in the primary cluster classified according to Period.

mixed over time, resulting in fewer outliers. I further attempted to classify the data according to Period, however there is a strong enough spatial bias in the periodized data that it was largely uninformative.

Finally, in classifying the LI data according to Period (Figure 9-23) it seems then that much of the Period 2 material is related to south-central Taurid sources. Keeping in mind contextual concerns from Square 64.94, this would indicate that the local mode of production was still in operation after the arrival of the Hittites. Further, noting that Period 1 samples stemmed exclusively from Square 42.10, the only time where we see distinctly Taurid-related bronzes in Area 1 is during the terminal occupation of the site. The other examples of Taurid material appearing in Area 1 are two Period 1 and 0 speiss fragments, three pieces of Period 3 copper, and two pieces of Period 4 copper. This suggests that the pre-Period 2 pattern of separation had actually been more stark than previously emphasized, while during and after the roughly 10-30 year span (Yener et al., 2019b, p. 337) of Period 2 this division began to break down amid a stretch of urban disintegration in Period 1.

## 9.4 A Brief Comment on the Pyrotechnical Installations:

Before beginning, it is worth stating from the outset that the evidence here is largely circumstantial. Nevertheless, given that this project is focused on metallurgy, it is worth making a few comments on the topic of pyrotechnical installations. As a loosely defined category, pyrotechnical installations have been a commonplace feature of the Tell Atchana excavations since their inception, manifesting as multi-chambered kilns, so-called pit furnaces, and the ubiquitous *tandır* – or vertical cylindrical bread ovens. This final category is of some interest here because thus far, any upright cylindrical installation with a relatively thin (~3-5cm) wall with sporadic temper has been put into this general category. Looking at the size of installations across all periods in Area 4, as well as Periods 4, 1 and 0 in Area 1 in relation to the evidence discussed above and in previous chapters, I would likely to tentatively suggest that some of these be considered crafting furnaces or hearths[17].

In particular, while the majority of *tandırs* measure between ~60-100cm in diameter, there is a smaller variant that runs between 30-40cm. Recalling J.D. Rehder's (2000) volume on the development of pyrotechnology, this latter dimension falls within the ideal range for balancing heat loss, air flow requirements, and minimizing ejecta from the furnace. Perhaps more importantly, however, are the contexts in which several of these have been excavated. There are,

[17] It is worthwhile to consider that such a distinction between some domestic and production hearths may be totally unnecessary. There is no reason that a small shaft furnace could not be used for cooking as well, though the larger *tandırs* are unlikely to be useful for smelting given their unfavorable thermodynamic characteristics nor for secondary working, given their depth and fuel inefficiency. Anecdotally, it is worth recalling that pottery kilns are commonly used even today for making bread or pizza on the side while there are a variety of other dishes such as *pepposo* that were traditionally produced by artisans in their furnaces. One of my own experimental smelting furnaces was repurposed in the off-season for roasting peppers and eggplants.

first off, the two fragmentary installations from Period 5 (fig. 4) in association with casting spill, huge amounts of ash, and a mold fragment. From Period 4, two of these installations were excavated in 64.72 and 32.53-54 (fig.6). Perhaps most importantly, however, were the three such installations accompanied by a square hearth from Period 3 in 64.94, as well as a further two in 64.83, and two from 64.94 in Period 2. For the 64.94 examples, regardless of which interpretation we select for the Period 2 evidence, there is a direct association between a host of evidence for smelting and alloying and these furnaces.

If we consider that these types of installation would be used primarily for smelting[18], then we can develop sort of a crude spatial organization for Area 4 Period 3. In this case, the eastern portion of the compound would be more closely associated with primary production activity. Meanwhile, given that much of our amorphous material and finished objects stem from the rooms surrounding the main courtyard, this is likely where most casting and finishing work would take place. This was probably carried out with the use of pot bellows (Davey, 1979) and crucibles as well as small hearths for annealing[19], which do not generally leave much trace behind. The courtyard, meanwhile, with its large quantities of chipped stone debris and larger stone debris that I tentatively hypothesize is bulk gangue material, would be where ore enrichment and the preliminary steps of other craft activities would take place. In addition, some of the gangue material is likely to have been further pulverized and used as abrasive, be it for polishing stone beads, to facilitate drilling of stone, or to polish metal objects. Regarding the huge amount of metallurgical and other debris from the street in 64.82 – as mentioned in chapter

[18] Without intact crucibles, the issue of using these hearths for alloying is very difficult to approach. Our one hint on this matter is AT22869, whose adhered ceramic material has a fabric and temper more similar to furnace material than our ceramics or few examples of crucibles from elsewhere.

[19] One such potential hearth was excavated in 64.73 Phase 4a in Locus 69.

3, it appears that the buildings at Alalakh were regularly cleaned. I suggest that the street deposits are in fact material that was cleaned out of the Area 4 compound in the course of these cleanings.

Regardless of the interpretation given to their context in Area 4, these installations should be studied further, in particular looking at soil samples from their bottoms and immediate surroundings. As it stands, our current understanding of early furnace technology is largely based on a few examples stemming from disparate regions of the Near East, oftentimes associated with much larger scale operations than that seen here.

## 9.5 Conclusions:

Over the course of this discussion, I have attempted to establish the analytical findings presented in previous chapters within their archaeological context and to extrapolate their implications to the broader assemblage. This has covered a timespan running from the early-17$^{th}$ C. BC to the early 13$^{th}$ C. BC, highlighting several trends of change and continuity in the metallurgical industry at Tell Atchana. Of interest here is that over the course of this roughly 400-year span, the fundamental technological style of the workshop assemblages – the raw materials and basic objects produced – remained remarkably consistent. The site-wide distribution suggests that in terms of types of material there is not a significant difference between the upper and lower mound occupations. There are enough exceptions, as seen in the molds and unique materials from 42.10, to suggest a more specific purpose and different system of organization on the upper mound, however. The general context of the Area 4 and 32.53-54 workshops suggests that these spaces were not used by dedicated metallurgical specialists, but rather that they were settings for similar sets of multi-craft activity. Finally, the coincidence of the decline in the metallurgical industry at Atchana with the establishment of direct Hittite rule over the city suggests, regardless of how one interprets the data, that the imposition of empire appears to have been ultimately detrimental to the local craft industry, as seen with the Agaria iron industry and the imposition of British colonial rule (Elwin, 1942, p. 273).

While it may seem unlikely that developments carried over such a long span could be tied together as part of a coherent social development, the evidence presented thus far forms a basis for defining a group of technically skilled, specialized craftspeople with a clear sense of technological style in Area 4 and 32.53-54. Instead of being specialized occupationally as we tend to imagine and as implied in texts – that is, purely as metalworkers – I suggest that they were specialists in the use of montane resources and fire. This is based on the simultaneous working of glass and metals; both are dependent on the use of ore minerals and the skillful deployment of fire for their production. At the same time, tools made from the metals produced formed an important part of the production sequence for both glass and lapidary work as drill bits and forming mandrels, while the byproducts of ore sorting may well have been crucial as abrasives for cutting, drilling, and polishing and as pigments. Indeed, in the form of the tools themselves, and particularly the square-sectioned drill bits (Yener et al., 2019c, p. 158), there is a substantial vein of long-term continuity that acts as its own marker of technological style.

The distinct LI signature of the Area 4 assemblage from Periods 5-3 and its concurrence with ore bearing workshop floor establishes a link between the periodically observed evidence of ore beneficiation and the long-term trajectory of the workshop. Not only does this further support continuity in technological style, in terms of craft specialization it highlights the continued independence of the non-palace industry. I have previously mentioned the access Tell Atchana had to long distance trade networks for a wide variety of materials including metals. Despite this, the Alalakh workshops relied on remarkably consistent sources of raw material, implying both a strong preference in materials and consistency in the transmission of knowledge for Area 4. By contrast, despite similar artifact forms and material classes, the Area 1 assemblage shows little of the specificity in ore sources. Taken in terms of craft specialization, this is indicative of routinization of production – a standardization of metal sources to reduce costs. More speculatively, from the Area 4 data we can infer varieties of knowledge surrounding material acquisition. First, the knowledge of where to acquire such ores, which one can imagine would usually be a closely guarded piece of specialist knowledge. Second, the knowledge of which ores were suitable for producing the desired product and how to appropriately treat them. With the largely demonstrated use of a specific set of regionally uncommon ores in the production of bronze, this is strongly indicative of ingrained practice.

Taking this speculation further, it is worth briefly hypothesizing on ore provisioning. One could reasonably suggest that the ore for Area 4 may have been traded into the city from a small mining settlement in the mountains, which could also account for the consistency of material found there. This would obviate the need for the local artisans to act as miner, smelter, and smith, which is certainly more appealing to modern conceptions of specialization and logistical efficiency. Instead, they only had to act as smelter and smith. However, this still means that we must account for the logistics of selling unsorted ore at a profit and the matter of ore beneficiation and enrichment. This process still involves a conscious and practiced selection of material that relies on similar sets of knowledge to those possessed by the miner. In either case, this illustrates an unusual situation where potentially greater technical proficiency goes hand in hand with a lesser degree of specialization.

If this discussion characterizes a particular technological style among some of the workshops at Tell Atchana, represented by particular types of base material, a practiced multi-craft organization, and particular types of tools, then we can also begin to propose the contours of developing craft specialization that appears to have undergone several modest shifts over time, though its ultimate purpose ostensibly remained consistent. In its earliest stages, the evidence at hand suggests that raw metal, glass, and stone were being brought to Area 4 from elsewhere and fashioned into both luxury goods (fig. 5) and tools for use in the trade of the workshop. Whether the raw metal and glass were produced in the city limits or elsewhere at this stage is not known, but the original sources are consistent with later periods. Given the small scale of production and ruined nature of the structures this represents low intensity production, with the artisans occupying the Period 6 ruins temporarily. From the very outset we see indications that the craftspeople working here should fall between Kuijper's (2018b) categories of common and master craftspeople. While there is a significant degree of repetition and production of mundane objects, we see a few flashes of objects requiring exceptional skill.

In Period 4, the scale of production appears to have increased, albeit not substantially, while the occupation of the area has become more permanent. Given this small scale, it is probable that crafting still represented a part-time activity in this area. Even in light of the suggestion that the manufacture of glass had now become an *in situ* activity, the associated infrastructure does not appear to have been enough of an investment to require constant operation while the associated debris is fairly sparse (Dardeniz, 2018). We are still unable to show whether metal is now definitively being produced in the city or not. The overall assemblage remains largely the same, suggesting a relatively well-defined niche for the workshop at this point. The identification of bronzes associated with speiss-related processes may represent a new addition to the technical repertoire but is more likely simply our first observation of this process. Nevertheless, it fits within the broader umbrella of locally sourced and produced materials. In 32.53-54, the small workshop displays a striking similarity in its assemblage and materials to that seen in Area 4. If we consider the associated technological style as an appropriate marker for these individuals, its presence in connection with such small-scale ephemeral activity would indicate that some of the Area 4 craftspeople may have started working as part-time attached specialists (nucleated corveé) in the palace. Further, if some of the Area 1 metals being material collected as tax remains tenable, it could also mark the inclusion of the Area 4 craftspeople as a new portion of the taxable population. Note that in Johnson et al. (2020), LIA data suggests that the MBA-LBA transition may be marked by a change in metal sources. More MBA data from Area 4 is necessary to support this, but it may show that these people introduced new metal sources into the urban economy. At the same time, this period is also associated with a shift in the ceramic assemblage of Area 4 (see; chapter 3) toward a more standardized assemblage with a greater emphasis on communal serving. In short, this period represents the integration of this crafting community into the urban fabric and economy of Alalakh.

Though the general assemblage and techniques remain largely consistent with previous activities, the scale of production in Period 3 increases substantially while the range of materials produced appears to broaden. Metal procurement in Area 4 is now clearly based on obtaining, sorting, and smelting ore from the south-central Taurus and a thus-far unconfirmed source to produce copper, bronze, and possibly a master Sn-alloy for more controlled alloying of bronze. Meanwhile, these activities are now contained within a cohesive compound. What this would appear to suggest is that the process that started in Period 5 had now become fully integrated with the urban landscape of the city, though the continued distinction between palace and Area 4 metal sources suggests limits to the degree of economic interaction between these areas. This notion is further supported by the broader range of material being produced, which implies a greater range of clientele[20]. That this same trend, minus indications of *in situ* primary production, is also reflected in the 32.53-54 workshop suggests that this is indicative of wider reaching social developments in the city at this time, mirrored both in the palace and in the lower mound.

What is interesting in this connection, however, is the contrast with the evidence presented from 42.10 for Period 3. Excavation of a large, multi-faceted stone mold including a cavity for what is probably a reasonably large axe, as well as smaller molds for fine jewelry stand in stark contrast to other evidence discussed so far. Taken at face value, a negative interpretation might suggest that the Area 4 workshop was less engaged in the production of larger castings. This hypothesis is difficult to support, however, as stone molds typically constitute a valuable part of a metallurgical kit and, failing a sudden disaster, are not likely to be left behind. In either case, the far more limited assemblage recovered from 42.10 for this period might indicate a more specialized variety of workshop than we have considered here – only future research can elucidate this.

Given this constant upward trend in the elaboration and prosperity of the metallurgical industry over the course of several centuries, it is curious that it seems to either collapse or undergo a complete reorganization at the end of Period 3, shortly after reaching its peak. This event coincides roughly with the Hittite assumption of direct control over Alalakh and drawing a connection between the two seems almost inevitable. Venturing into the realm of speculation,

[20] In the future, studies of metals from more mundane contexts should be compared against the corpus presented here to get a better idea of the full range of products available.

one potential option is that early in this process, the artisans working here fled in the face of domination by a foreign power. Based on my discussion of highland populations generally and ethno-occupational groups more specifically alongside the apparently close links between the Area 4 craftspeople and the highlands, this seems to be a distinct option. Alternatively, the new Hittite administration may have attempted to initially centralize craft activities elsewhere, though in Lehner's (2015, p. 184) assessment of Boğazköy metallurgy, organization in the Hittite capital tended to be decentralized and semi-attached. Furthermore, given the organization of the Area 4 Workshop as a self-contained organism with control over all aspects of the production process, centralization under circumstances deemed unfavorable by the craftsmen is likely to have been counterproductive.

In either case, the usual explanations that would be offered in this type of situation such as broken-down lines of supply for copper and tin, or broader societal collapse do not seem to fit, leaving us with something of a mystery. That this collapse is accompanied by a general paucity of metal across the site also suggests that whatever happened affected the whole city and its general metal supply. There are a range of questions to be addressed here, but they will require further period-specific data to be answered.

Keeping in mind the archaeological concerns raised above, in Period 2, when the presence of Hittite administration is embodied by the Northern and Southern Fortresses, the recurrence of local metallurgy – absent its other multi-craft features – with an analogous technical appearance to that of earlier levels is curious and somewhat difficult to explain. Given its location and archaeological context, it would be much more akin in structure to the Period 5 industry discussed above, appearing ephemeral and small in scale. Regardless of how we interpret the data from the end of Period 3 and Period 2, the one secure conclusion to be drawn is that this was a period of flux for the metallurgical industry – at least as it related to the general population and the palace. The metal assemblage of the Southern Fortress stands out in the quality of its objects, among them the astounding three-spiked axe (Yener et al., 2019a, p. 338), meaning that there were fine metal goods to be found, they merely appear to be localized in seats of imperial authority. The periodized LI data suggest, however, that these were still produced using materials of the local system.

The gathered evidence for Period 1 is compelling, but too limited to draw secure conclusions. At this point, it appears that the drop observed in metallurgical activity during Period 2 was corrected to a certain degree. As far as we can tell from our limited information, the materials involved are still largely the same, though AT21470 may illustrate smelting aimed at larger production volumes. Finally, Period 0 can simply be shown as an example of relative continuity in technological tradition and its persistence even in the relative absence of a strong authority immediately following the abandonment of the city.

Several points can be drawn from the discussion so far regarding the nature of the metallurgical industry at Tell Atchana. First and foremost, though the Area 4 industry developed attachments to the city administration over time, its initial manifestation appears to have been as an independent system manufacturing luxury goods. Neither proximity nor other finds such as seals or sealings suggest an attached context. The palace does not appear to have played a significant role in its establishment, nor does it appear significantly involved in providing metal to external workshops. Despite covering a 400-year time span, the available evidence does not suggest much shift in the technological style of this industry, only of its scale. The shifts in scale, however, are generally limited to the Area 4 compound – the involvement of this system with the palace, though ongoing, was limited. The palace does appear to have had other more specialized workshops that remain to be investigated. As for what motivated the observed shifts in scale, it appears to be less associated with technological development or capacity, and more so with cultural tastes. Based on the analytical evidence, the artisans appear to have had the requisite knowledge to achieve much larger production volumes than they appear to have been working with.

In explicit craft specialization terms, this assemblage has considered two well-defined production units (32.53-54 and Area 4) and a third more poorly defined unit (42.10/42.29) based on physical separation and standardized material sources. The difference in scale between 32.53-54 and Area 4 at the peak of production is striking, with Area 4 representing a significantly larger and more organized production unit with defined working spaces and a substantially larger absolute quantity of production debris. Interestingly, the "household" scale of production in Area 4 highlighted by the co-occurrence of domestic and production activities outstrips that of the "workshop" industry of 32.53-54 or 42.10/42.29, which runs counter to the usual expectations of the craft specialization literature (Costin, 1991, p. 16). A simple comparison of ratios of metals between different areas of the mound is enlightening; taking Areas 2 and 3, which show some craft activity but very little related to metals, alongside Area 4 and the newly excavated parts of Area 1 the ratios are 1.7:7.7:3. While we cannot directly address the ratio of producers to consumers (Costin, 1991, p. 21), if we consider Areas 2 and 3 a site of general consumption, Area 4 a site of production, and Area 1 a site of production and consumption, the pattern is reasonably clear, the Area 4 industry is extensively specialized.

The context of the Area 4 production was, by all accounts, independently organized based on its location away from the palace or other administrative architecture and its distinct resource procurement networks. 32.53-54, being located within the palace precinct, can be clearly assigned as an attached workshop and its shared resource procurement with other parts of the palace infrastructure identifies the palace precinct as an integrated system. Considered alongside the relative scales of production, this suggests that during the LBA at Alalakh, private demand was a more significant driver in expanding craft production and the involvement of the palace was largely unnecessary. Given a lack of comparative regional data, it is not possible to reliably determine concentration, though the textual record implies dispersed workshops. Without knowing the character of these textually attested workshops, there is little to be said. In terms of intensity, the results are somewhat counter-intuitive and yet fully predictable. The 32.53-54 workshop, by virtue of its attached character and relatively limited number of non-production activities in evidence, can be defined as full-time. However, the low level of investment in facilities suggests that it was not constantly in operation. By contrast, the variety of domestic and non-metallurgical craft activities from Area 4 suggests that the household was engaged in almost full-time craft production, but not necessarily full-time metallurgy. In both cases, the variety of craft activities and the range of objects produced appears relatively un-standardized, despite the technical capability and sophistication seen analytically.

Realistically 42.10 and 42.29, though they provided important samples for an overall assessment of the technological style of the site, provide us with only an impressionistic view of the types of specialization present. They were obviously tapped into the same resource networks as the 32.53-54 workshop; however, the quality of the molds and the greater number of pyrotechnical installations suggests a greater investment in equipment. This is a feature associated with an intensity of production associated with full-time specialization and the frequent presence of molds would facilitate standardization (Costin, 1991, pp. 16–17). As noted above, however, the availability of molds in Area 4 cannot be excluded, even if none were excavated. In any case, it does highlight the specialized used of space within the palace precinct, which sets this area apart in terms of how it operated.

Considering that the original intent of Costin's discussion of craft specialization was to use ratios of producers to consumers as an index for specialization (Costin, 1991, pp. 21–22), it is not possible with the current dataset to make a judgement based on this criterion. More substantial exposures in Areas 2 and 3 would be necessary to provide a diachronic assessment of non-palace consumption in settings where metalworking, though present, was not a primary economic activity. What the evidence does highlight is variations in kinds of specialization, with a particularly clear difference between state and non-state configurations. Much like the texts suggest, state configurations have resource networks that appear to cover a broader catchment and the workshops themselves appear suited to specific purposes. For independent workshops, though their resource procurement is standardized in a sense, and markers of intensity and scale suggest very specialized activity, the variety of economic activities taking place would normally lead to Area 4 being considered unspecialized. A strong argument can be made that both settings reflect situations where the practitioners involved were spending most of their time on crafting to supply external consumption as an economic activity, but Area 4 shows that we should allow for specialization in more than a single craft, perhaps reflecting specialization in the exploitation in an ecological niche rather than a specific material.

# *10 Metallurgy at Alalakh in Context*

In summarizing this work, I would like to return to the three questions that I established as my primary guides in carrying out this study:

- What technical practices characterize the metallurgical assemblages of Areas 1 and 4 of Alalakh?
- How does the organization of production manifest within the city of Alalakh?
- What is the cultural representation of metals and metal technologies in the Near East and how does that compare to the archaeologically derived picture?

As is by now apparent, many of the hypotheses I had established at the outset of this study, based on existing models of metallurgical development, have proven inaccurate. Notions about the primacy of the state in metal procurement networks are difficult to maintain, being superseded by the possibility that except in exceptional circumstances this role falls to groups with unrestricted access to highland resource zones. This also means that associated technologies, though responsive to the appetites of sedentary lowland communities, were largely in the hands of highland groups until later periods when states developed more substantial capacity to project power into highlands. More locally, though there are consistent patterns of skill across the site and shared patterns of material use in both excavation areas under consideration, they appear to only be minimally integrated. Finally, the textual record, though it agrees with the archaeological evidence on many counts, shows several areas where re-interpretation may be needed. A point to be emphasized here is that we must be careful about how we extend textual evidence to systems beyond the palace walls, especially when it involves necessary interactions with landscapes of resistance.

## 10.1 Technological Style at Tell Atchana

I have shown here that the technological style of Alalakh was exceptionally varied in terms of its technical processes and organization of production, with clear implications for the role of technological style and systems in meeting the needs of a consumer populations. At the heart of this is a strong emphasis that two parallel technological systems were in place in this ancient urban center. For the elites occupying the Palace and Temple annex, one system of unclear contours showed a tendency toward acquiring metals from a variety of different sources, engaged in the production of large tools, votive objects, jewelry, as well as more mundane objects. Some apparent production areas show similar multi-craft configurations to the Area 4 Workshop, but the scale is smaller and until the very end stages of occupation, the metallurgy is mostly secondary. In the Area 4 Workshop, an industry based primarily on the use of a handful of ore sources in the south-central Taurus. The primary products that are left to us appear to have been

| Palace and Temple Annex | Area 4 Workshop |
|---|---|
| **Metals:**<br>Broad resource catchment, uncertain sourcing<br>Large Tools<br>Small Tools<br>Votive Objects<br>Jewelry<br>Weapons | **Metals:**<br>Two principal raw material sources<br>Small Tools<br>Vessels<br>Composite object components<br>Weapons |
| **Non-Metals:**<br>Chipped Stone (Flint, Obsidian)<br>Shell<br>Ivory<br>Faience | **Non-Metals:**<br>Chipped Stone (Flint, Obsidian)<br>Carnelian<br>Serpentine<br>Quartz<br>Ore Minerals<br>Shell<br>Glass<br>Faience<br>Bone |

Table 10-1: Table summarizing the general character of material from the Palace/Temple Annex workshops and the Area 4 Workshop.

small tools, maybe vessels, as well as sheet that may have been used for cladding furniture. Alongside these activities, they also produced stone beads and potentially glass, activities also involving the use of montane resources.

In terms of skill, both areas display a similar repertoire of materials and abilities. They made significant use of bronze and refined copper for their objects, while raw copper finds use primarily in artifacts that would be considered short-lived or disposable, such as arrowheads and gravers. In decorative processes there is an apparent similar intent, even if the outcome was largely similar; where in Area 1 we see the use of silver-alloy cladding, in Area 4 there is tinning through probable direct reduction of tin ore on an artifact surface. Taken alongside other evidence of plating at Alalakh (Yener, 2014, 2007), this is an indication for traditions of metallic polychromy. Both industries were primarily luxury-oriented, though the mold from Area 1 at least points to some utilitarian production in the Temple Annex while the Area 4 assemblage also shows a variety of small tools. In short, both workshops appear to have been populated with individuals ranging between common and master artisans (Kuijpers, 2018b). Given the similarity of style in secondary working, they may have been the same people, working as full-time specialists in a part-time attached capacity.

Under normal circumstances one might argue that the clientele for each context was largely the same, given the similarities. However, the distinct division on the assemblage based on lead isotope analyses makes this most improbable. Perhaps, the Area 4 workshop served the needs of the non-royal nobility, the *mariyannu*, as well as other craftspeople. What mixing we do see between the Area 1 and 4 metal pools would reflect the textually attested disbursement of metal to workshops for palace projects, as well as the probable acquisition of metal from smaller producers as tax. Ultimately this is in agreement with hypotheses of multiple parallel metal procurement networks, though many of these still center the state as a prime mover in driving primary production (Rehren and Pusch, 2012; Sherratt, 2016; Stos, 2009)

Perhaps most surprising was the realization that primary production running the complete extent of the metallurgical *chaîne opératoire* was taking place in the Area 4 workshop. It remains unclear is this activity supplied all or part of the metal used in this production. If we accept the Taurid identification of sources for the raw copper in used, then the answer is relatively simple – the workshop largely supplied itself. If the Cypriot identification is correct, then the answer is more complex and surprising – this workshop had access to Cypriot copper of the Solea axis, the source of the much-discussed oxhide ingots (Stos-Gale et al., 1997), while the palace does not appear to have. In either case, the result is that the business of the workshop was largely independent, even if the craftspeople spent part of their time working in the palace.

More significant is the meaning of this evidence in relation to the broader question of technology characterized as systems of knowledge. This means knowledge of where to acquire resources, how to process them, and finally how to work them. For Area 4 this meant either knowing the location of mines and going themselves or being acquainted with people who did and could bring unprocessed raw material to the city. Taken in sum with the highland character of other resources worked in Area 4, this provides grounds for arguing that the artisans here originated from or had social ties with the highlands and leveraged them in the execution of their trade. These may be my co-called indigenous metallurgists. Appropriate knowledge and resource access, combined with the risk of flight represented by the proximity of highland zones where these people may have had social ties, meant that at Tell Atchana the palace was not in a position to dominate the local metallurgical industry in the same way as at Ebla, Ugarit, or Mari. In these cases, acquisition of metal by state-mediated trade facilitated control of resources for a population of secondary metalworkers.

The specificity of knowledge of the smiths at Tell Atchana is exemplified in the use of speiss-related processes to produce bronze. It can be strongly suggested that they were engaged in the use of a very specific resource to produce a specific and often difficult material (Craddock et al., 1987; Kassianidou, 1998; Rehren et al., 2012; Thornton et al., 2009) that was then used in the production of bronze. The importance of bronze has been stated hyperbolically with its comparison to the strategic importance of oil in the modern world (Bell, 2012). This data has the potential to impact not just how we perceive the tin trade of the Late Bronze Age, but also carries with it the implication that the vehemently resisted identification of Anatolia as an early tin source may indeed have been correct. This impinges on narratives that look further east for the beginnings of bronze metallurgy and has the potential to redefine the character of the early 2nd millennium Old Assyrian Trade Network (Larsen, 1976; Veenhof and Eidem, 2008) less as a bearer of a crucial new technology and more as an opportunistic innovation that simplified the configuration of an existing process. Being fully aware of the acrimonious debate I am wading into (Muhly, 1993, 1985; Pernicka, 1998; Yener and Özbal, 1987; Yener and Vandiver, 1993) and the furor this suggestion may engender, I maintain that this was likely a very limited, localized tradition of bronze making with potential similarities to processes seen at Tell al-Judaidah in the Early Bronze Age (Adriaens et al., 2002). If the “tin of Kizzuwatna (Cilicia)” (Košak, 1982, p. 77) mentioned in Hittite texts referred to this material, I would be surprised given the difficulty and unpredictability that its use must have presented. On present evidence, I would suggest that this method simply represented a way for non-elites to access bronze and subvert centralizing tendencies.

## 10.2 The Organization of Production

While the focus of narratives concerning Bronze Age metallurgy has been the link between complex technologies, complex societies, trade, and the organization of production as illustrated in the data from the southern Levant and Cyprus, the general body of evidence from Anatolia and the present data from Tell Atchana propose a parallel system. While the models for the Levant and Cyprus, emphasizing the role of states and trade in the creation of increasingly centralized metal industries are largely efficacious for those settings, in Anatolia "balkanized technological horizons" (Yener, 2000) riven by complex topography and social boundaries resulted in de-centered patterns of organization. Although Yener suggested that this resulted primarily in the development of a two-tier organization, with the primary tier being highland controlled and feeding lowland secondary industries, this appears to have only been part of the picture. At Alalakh the primary tier infiltrated the secondary tier and existed alongside it, showing that in some scenarios the integration of hierarchical productive chains was not inevitable.

The material from metal workshops excavated by Woolley (Müller-Karpe, 1994, pp. 95–96; Woolley, 1955, pp. 120, 130) in the palace area seems to support the notion that the palace industries were minimally integrated with the lower town. Within the palace, a collection of apparently raw copper in association with crucibles suggests that when the palace did receive copper from the lower-town industries, it was in the form of raw agglomerations, rather than processed ingots. One might imagine that the HSP samples from 42.29 and 32.53-54 are examples of precisely this material. Potentially given to the palace as tax, it was up to the palace workshops to refine and cast this material into ingot forms. As noted in AlT 431, copper was "made into bars." Though Wiseman (1953, p. 14) took this to mean that the palace received the metal in bar form, the archaeological evidence suggests that they had to cast it themselves. Of course, the LI data suggests a relatively strong degree of separation, and so while this may have been part what took place in palace workshops, we can also easily imagine that the larger ingots recovered from the palace during the Woolley excavations were acquired through inter-palatial trade (Kaptan, 2017).

Beyond this set of copperworking debris, other workshops were also found in the palace, associated primarily with the production of jewelry (Müller-Karpe, 1994, Pl. 53). This agrees well with finds from 42.10, with the caveat that the latter also yielded the large multi-faceted mold discussed previously. In general, the palace workshops appear to be more specialized facilities, though the material from 32.53-54 does illustrate the presence of multi-craft areas as well. Though the palace is the only location where jewelry molds have been excavated, in the private houses there are further indications for a goldsmith's workshop based on finds of gold ingots (Woolley, 1955, p. 196). It is, overall, relatively difficult to characterize the palace industry based on the inconsistent evidence. Furthermore, that gold has also been found in Area 4 in the form of flakes also calls into question the extent to which the palace may have had control over this material.

Regarding my initial hypotheses for question 2, suggesting that any primary production in the city was likely to be palace controlled, it is clear that my basic assumptions were wrong. Founded on earlier evidence from sites such as Norşuntepe that displayed primary production in palace contexts (Schmidt, 1996; Zwicker, 1980), I had not accounted for the possibility of primary production in a non-palace controlled environment. In this case, the roles were reversed, and it was the independent workshop of Area 4 that had access to fresh metals. The attached workshops of the palace appear to have been left to the use of recycled and mixed material.

There remains further research to be conducted on the palace assemblage in this light, however, it is not a counter-intuitive outcome. If we assume that the palace had a larger scale of secondary production, the Area 4 industry in evidence being quite small-scale in nature, then the need for recycling metal objects that were no longer useful would help serve this production. Furthermore, given the role of palaces as aggregators of material through taxation and trade with extensive links between one another, the level of variability observed in potential metal provenance for the associated assemblage is unsurprising.

A new working hypothesis may be proffered, then – unless the state is able to effectively monitor access to metal resources, such as in settings where the primary mode of acquisition is trade (Ugarit and Ebla) or where ore sources are relatively localized and fall within a reasonably contiguous settlement pattern (Levant and Cyprus), primary production is more likely to be an independent industry. The corollary to this, as seen at Alalakh, is that the urban industry itself is also likely to be mostly independent with the caveat that residency within the city, and the access to an active market that it provides, would require periods of attached labor. That this model decouples palaces from primary production to a certain extent would tend to suggest that the expansion and elaboration of metallurgical production during the LBA was in some places a result of private initiative in the highlands, where these communities saw an opportunity to take advantage of expanding appetites for highland products in lowland wealth finance systems.

## 10.3 The Palatial Perspective – The Alalakh Texts and their Relation to the Data

In much of this study, I have been critical of text-based perspectives to a significant degree because the ancient documents reflect the view of a particular economic and political bubble. In as far as the elite of the ancient Near East have shown themselves to be aggrandizers with a myopic set of concerns and interests, trusting their documents without verifying the facts of action is a questionable practice at best. With this in mind, the Alalakh archives agree with the archaeological evidence on many counts. In most instances the archaeological evidence simply suggests potential re-interpretations.

Regarding the organization of production, as Müller-Karpe (1994, p. 97) has previously pointed out, the Alalakh texts do provide evidence for a decentralized system outside of the palace. This takes the form of census lists (Dietrich and Loretz, 1969) that mention smiths in other towns, as well as documents recording the disbursement of metals to these smiths for the production of specific goods (AlT 427, 366, 184, 397, 398, 402). Similarly, AlT227 documents 16 smiths in a "household" producing goods for a service obligation. These texts give an impression that production at Alalakh was carried out in highly specialized nucleated workshops. This is not supported by the evidence from Area 4, which indicates multi-craft community production. In this light, it seems probable that in some cases terminology such as "house of smiths" should refer to an occupational grouping, as opposed to a physical location. Furthermore, the multi-craft nature of Area 4 calls into question strict occupational categorizations such as "smith", raising the possibility that administrative documents present an overly strict or idealized image of specialization patterns.

In another problem of terminology, the broad reliance of the Alalakh texts on the term URUDU, as opposed to more specialized terminology in other settings bears comment. In chapter 5 I discussed terminology on metals, suggesting that the degree of specificity and elaboration in the vocabulary used for specific materials was indicative of the relative level of involvement of the administration in metalworking. If this is taken as reasonable, the impoverished language of the Alalakh palace, especially in light of the rich variety of material present at the site including the most basic distinctions of raw and refined copper, suggests minimal acquaintance with the local industry and its activities.

Despite an acknowledgement of decentralized organization, the texts have still tended to give the impression that the palace received processed metal as ingots that it then distributed to workshops (Müller-Karpe, 1994, p. 97; Wiseman, 1953, p. 14). In other words, though decentralized, the workshops are still presented as attached. This position can no longer be maintained without modification. Even if we argue that the final products resulting from such work contracts would have been sent away from the workshops, the amorphous working debris would still be expected to carry the signature of palace copper with its presence in the assemblage being in proportion to the amount of work the atelier performed for the palace. This means that at least for the Area 4 Workshop, the palace was not likely to be a major supplier. Furthermore, that the only speiss-bronzes from Area 1 occur after the urban fabric of the city had largely unraveled may indicate that there was even greater separation between the two industries than suggested here. Future research will need to examine the metal assemblages of the outlying towns and other contexts at Tell Atchana to see how representative this situation was. It is possible, after all, that this workshop is an aberration – other examples may show a closer relationship to the palace.

Adding to the decentralization of the palace as an arbiter of valuable resources, two texts from the MBA Level VII archive, AlT368 and 370, are interesting. Though several centuries older than the events discussed here, meaning that they should be understood as illustrative of a general class of activity, they mention “illegally acquired” silver and “illegal dealers” of silver. This language suggests that the palace sought to control at least the circulation of precious metals (vis-à-vis my statement on sumptuary laws above) while also acknowledging that precious metals were acquired through middlemen, some of whom were not on good terms with royal authorities. Taking this a step further, this implies that the palace struggled to control economic resources within its own sphere of authority.

In terms of the social status of smiths, the textual evidence is somewhat ambiguous. AlT 69 records a smith as being as witness in the purchase of a slave before the king, while AlT 213 is a list of landowning smiths. According to von Dassow (2008, pp. 283–284), individuals acting as witnesses before the king may be considered as part of the royal court, in which case some level of elevated status was possible. Landownership, however, does not appear to have been unusual and so its relationship to social status is unclear (von Dassow, 2008, p. 332). In this respect, the archaeological evidence presented earlier, showing a range of imported fine wares in the Area 4 Workshop suggests the former. If we take the diachronic evaluation of chapter 9 at face value, however, the moderate-to-high status of the Area 4 assemblage appears to be the summation of a long term process stretching over several generations, where the starting point appears to have been decidedly impoverished.

## 10.4 Conclusion

My final comments primarily concern the diachronic development of the Area 4 Workshop within the broader milieu of Tell Atchana. Though there is no concrete evidence that would tie together the various people inhabiting this small part of the mound together over the course of about 200 years, the consistency of the allocation of space and materials used bespeaks a certain continuity. In order to strengthen the case, analyses of MB assemblages from Area 4 are necessary. If the apparent shift in ore sources in the transition to the LBI as documented in Johnson et al. 2020 is robust, then a stronger case can be made that a new population settled here at this time and brought with them a new technological system based on the exploitation of different raw materials as well as the working not just of metals but also of stone. Even in lieu of this data, the archaeologically observable shift in Area 4 settlement between Periods 6 and 5 and the accompanying coherent development of activity there into Period 3 suggests as much.

In this case it appears that these people maintained an identity as craftspeople through the duration of this long stretch while also maintaining themselves as distinct from the local palace economy. To me this is likely linked to an identity rooted in their craft and the highland zones that their resources – if not the people themselves – hailed from. Maintenance of this identity over such a long span was likely accomplished both through the transmission of technical practice and cultural values in education and practice. This would include those activities I have identified in the archaeological record of Tell Atchana, as well as during trips into the mountains to procure raw materials. Despite the option to use more locally available material, these individuals maintained an association with the south-central Taurus and the resources located there. Though they could have simplified their productive systems through the use of traded copper and tin, they appear to have continued to rely on material they could produce themselves. All these phenomena manifest in the previously discussed ethnographic record, tying together aspects of technological systems, style, and the *chaîne opératoire* as defining features in crafting culture at Alalakh.

# *Appendices*

# Appendix 1: Summary of Metallographic Observations for Cu-base Samples

The following list provides a general summary of metallographic observations for not-entirely-corroded Cu-based samples evaluated in the course of this study. More detailed information, along with micrographs for all samples can be found in the accompanying database. Organization is first according to material and then object type. AT# is the original excavation number for each object and can be used to reference context data within the excavation archives.

| ***AT#*** | ***Object Type*** | ***Material*** | ***Grain Type*** | ***Twinning*** | ***Strain Lines*** | ***Sulphide Inclusions*** | ***$Cu$-$Cu_2O$ Eutectic*** | ***Major Phases*** |
|---|---|---|---|---|---|---|---|---|
| *21204* | Shaft | Cu-Ag-Ni Alloy | Equiaxed and Eutectic | Yes | No | Yes | No | Cu-Ag, Cu-Ni |
| *8915* | Wire | Cupronickel | Equiaxed | Yes | No | Yes | No | Cu-Ni |
| *569* | Amorphous | High Tin Bronze | N/A | No | No | Yes | No | δ-bronze |
| *19172* | Amorphous | High Tin Bronze | Dendritic | No | No | Yes | No | α-bronze, α+δ eutectoid |
| *19177* | Amorphous | High Tin Bronze | Dendritic | No | No | Yes | No | α-bronze, α+δ eutectoid |
| *19447* | Amorphous | High Tin Bronze | Dendritic | No | No | Yes | No | α-bronze, α+δ eutectoid |
| *19926* | Amorphous | High Tin Bronze | Equiaxed | ? | Yes | Yes | No | α-bronze, α+δ eutectoid |
| *21374* | Amorphous | High Tin Bronze | Dendritic | No | No | Yes | No | α-bronze |
| *25650* | Amorphous | High Tin Bronze | Dendritic | No | No | Yes | No | α-bronze |

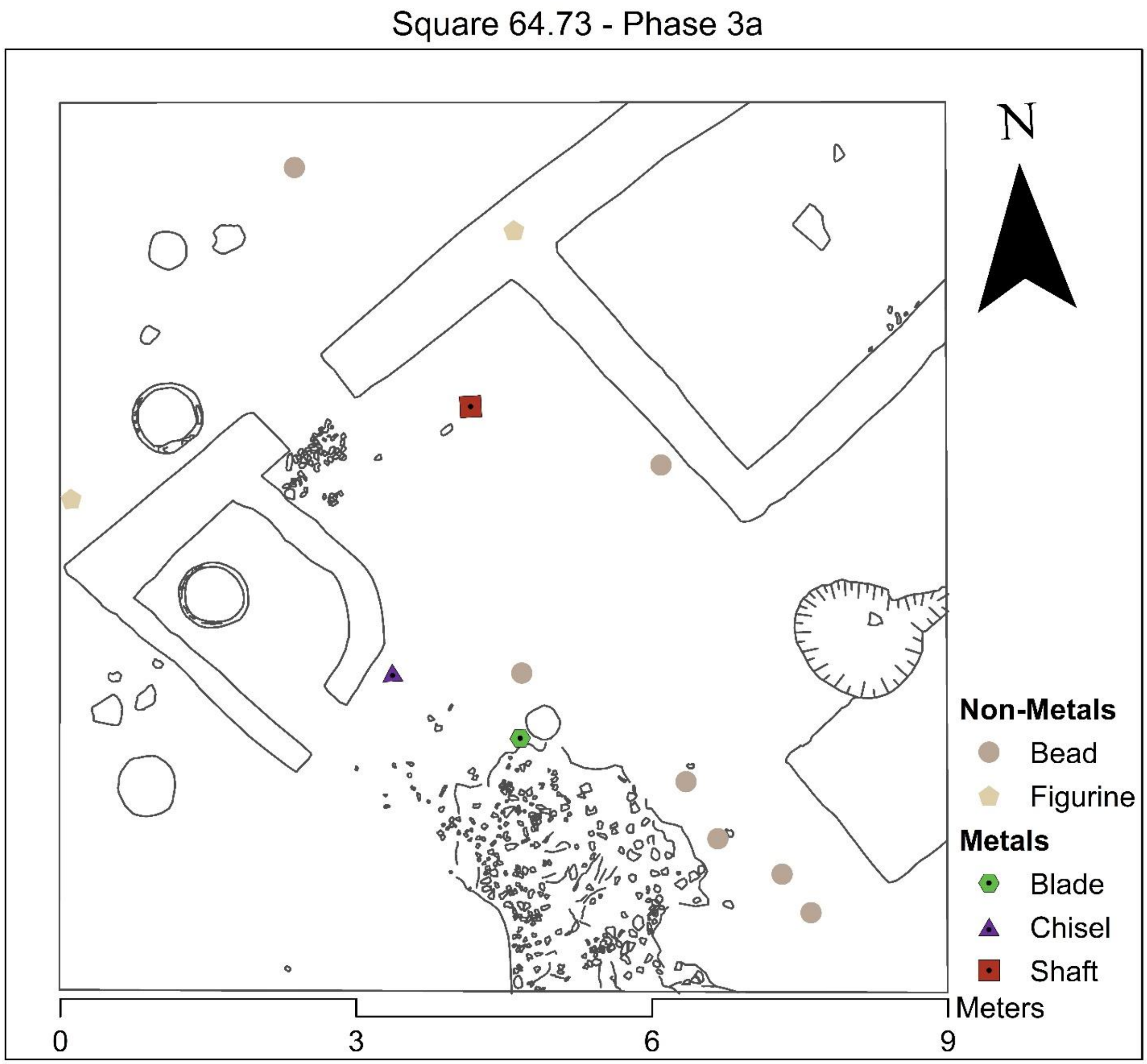
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *21778* | Awl | High Tin Bronze | Equiaxed and Deformed Equiaxed | Yes | Variable | Yes | No | α-bronze |
| *8676* | Crescent | High Tin Bronze | Equiaxed | Yes | No | Yes | No | α-bronze |
| *4007* | Flow | High Tin Bronze | Dendritic | No | No | Yes | No | α-bronze |
| *7288* | Pin/Needle | High Tin Bronze | Equiaxed | Yes | Yes | Yes | No | α-bronze |
| *8037* | Pin/Needle | High Tin Bronze | Deformed Equiaxed | Yes | Yes | Yes | No | α-bronze |
| *4113* | Rim | High Tin Bronze | Equiaxed | Yes | No | Yes | No | α-bronze |
| *4318* | Shaft | High Tin Bronze | Equiaxed | ? | Yes | Yes | No | α-bronze, α+δ eutectoid |
| *19158* | Shaft | High Tin Bronze | Deformed Equiaxed | Yes | Yes | Yes | No | α-bronze |
| *21332* | Shaft | High Tin Bronze | Equiaxed | Yes | No | Yes | No | α-bronze |
| *21743* | Shaft | High Tin Bronze | Equiaxed | Yes | Yes | Yes | No | α-bronze |
| *4148* | Sheet | High Tin Bronze | Equiaxed | Yes | Yes | Yes | No | α-bronze |
| *8904* | Sheet | High Tin Bronze | Equiaxed | Yes | Yes | Yes | No | α-bronze |
| *20433* | Sheet | High Tin Bronze | Deformed Equiaxed | Yes | Yes | Yes | No | α-bronze |
| *24677* | Tack/Nail | High Tin Bronze | Equiaxed | ? | ? | Yes | No | α-bronze, α+δ eutectoid |
| *4101* | Amorphous | Low Tin Bronze | Dendritic | No | No | yes | No | α-bronze |
| *4309* | Amorphous | Low Tin Bronze | Dendritic | No | No | Yes | No | α-bronze, |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | α+δ eutectoid |
| *8020* | Amorphous | Low Tin Bronze | Dendritic | No | No | Yes | No | α-bronze |
| *8040* | Amorphous | Low Tin Bronze | Dendritic | No | No | Yes | No | α-bronze, α+δ eutectoid |
| *4048_1* | Amorphous | Low Tin Bronze | Dendritic | No | No | Yes | No | α-bronze, minor α+δ eutectoid |
| *18494* | Awl | Low Tin Bronze | Equiaxed | Yes | No | Yes | No | α-bronze |
| *21510* | Awl | Low Tin Bronze | Deformed Equiaxed | Yes | Yes | Yes | No | α-bronze |
| *21536* | Awl | Low Tin Bronze | Deformed Equiaxed | Yes | Yes | Yes | No | α-bronze |
| *20450* | Chisel | Low Tin Bronze | Equiaxed and Deformed Equiaxed | Yes | Variable | Yes | No | α-bronze (ghost coring) |
| *8498* | Pin/Needle | Low Tin Bronze | Equiaxed | Yes | No | Yes | No | α-bronze |
| *8499* | Point | Low Tin Bronze | Deformed Equiaxed | Yes | Yes | Yes | No | α-bronze |
| *8002* | Rim | Low Tin Bronze | Cored Recrystall-ized | Yes | No | Yes | No | α-bronze, α+δ eutectoid |
| *21454* | Strainer | Low Tin Bronze | Equiaxed | Yes | No | Yes | No | α-bronze |
| *7297* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe |
| *8061* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe |
| *8089* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe, Matte |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *8226* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe |
| *8346* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe |
| *8620* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe |
| *8672* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe |
| *8686* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe |
| *19901* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe, Matte |
| *22853* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe |
| *23953* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe |
| *25628* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe |
| *25637* | Amorphous | Raw Copper | Equiaxed | No | No | Yes | No | Cu, α-Fe |
| *8666* | Blade | Raw Copper | Deformed Equiaxed | Yes | Yes | Yes | No | Cu, α-Fe |
| *8237* | Point | Raw Copper | Deformed Equiaxed | Yes | No | Yes | No | Cu, α-Fe |
| *23960* | Shaft | Raw Copper | Deformed Equiaxed | Yes | No | Yes | No | Cu, α-Fe |
| *4147* | Amorphous | Refined Copper | Equiaxed | No | No | Eutectic | No | Cu |
| *8322* | Amorphous | Refined Copper | Equiaxed | No | No | Eutectic | No | Cu |
| *8465* | Amorphous | Refined Copper | Equiaxed | No | No | Eutectic | No | Cu |
| *18635* | Amorphous | Refined Copper | Equiaxed | No | No | Yes | No | Cu |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *20717* | Amorphous | Refined Copper | Equiaxed | No | No | Eutectic | Isolated Inclusions | Cu |
| *20765* | Amorphous | Refined Copper | Equiaxed | No | No | Yes | Yes | Cu |
| *21393* | Amorphous | Refined Copper | Equiaxed | No | No | Eutectic | No | Cu |
| *25629* | Amorphous | Refined Copper | Equiaxed | No | No | Yes | No | Cu |
| *20638* | Chisel | Refined Copper | Equiaxed | N/A | N/A | Yes | No | Cu, Cu-Ag sheet |
| *24079* | Ingot | Refined Copper | Deformed Equiaxed | Yes | Yes | Yes | No | Cu |
| *23902* | Point | Refined Copper | Deformed Equiaxed | Yes | No | Yes | No | Cu |
| *24621* | Point | Refined Copper | Equiaxed | Yes | No | Yes | Isolated Inclusions | Cu |
| *8048* | Sheet | Refined Copper | Equiaxed | Yes | Localized | Yes | No | Cu |
| *18608* | Sheet | Refined Copper | Deformed Equiaxed | No | Yes | Yes | No | Cu |
| *8906* | Wire | Refined Copper | Deformed Equiaxed | Yes | Yes | Yes | No | Cu |

Appendix 2: 64.73 Phase 3a Finds



# Appendix 3: SEM Bulk Metal and Slag Analyses

These are the bulk compositional values for intact metal samples analyzed at the Cyprus institute according to the methodology described in section 6.1, where standard analysis values are also reported. For metals, all values given here are in weight percent. Based on metallographic results, O values should typically be understood as indicating minor corrosion. For slags, all reported values are given in oxide percent with O determined by stoichiometry.

n.d. = not detected

Metal analyses:

| *AT#* | *Material* | *O* | *S* | *Fe* | *Co* | *Ni* | *Cu* | *As* | *Ag* | *Sn* | *Sb* | *Pb* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *569* | High Tin Bronze | n.d. | n.d. | n.d. | n.d. | n.d. | 66.0 | 0.6 | n.d. | 33.5 | n.d. | n.d. |
| *4007* | High Tin Bronze | 1.0 | 0.2 | n.d. | n.d. | n.d. | 91.0 | 1.0 | n.d. | 6.9 | n.d. | n.d. |
| *4048_1* | Low Tin Bronze | 0.6 | 0.2 | 1.4 | n.d. | n.d. | 92.1 | 1.0 | n.d. | 4.7 | n.d. | n.d. |
| *4101* | Low Tin Bronze | 0.8 | 0.2 | n.d. | n.d. | n.d. | 95.2 | 0.8 | n.d. | 3.1 | n.d. | n.d. |
| *4113* | High Tin Bronze | 0.5 | n.d. | n.d. | n.d. | n.d. | 85.1 | 0.6 | n.d. | 13.7 | n.d. | n.d. |
| *4147* | Refined Copper | 0.6 | 0.6 | n.d. | n.d. | n.d. | 98.9 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *4148* | High Tin Bronze | 0.6 | n.d. | n.d. | n.d. | n.d. | 89.0 | 0.7 | n.d. | 9.7 | n.d. | n.d. |
| *4309* | Low Tin Bronze | 0.7 | n.d. | 0.2 | n.d. | n.d. | 95.2 | 0.8 | n.d. | 3.1 | n.d. | n.d. |
| *7288* | High Tin Bronze | 0.6 | 0.2 | n.d. | n.d. | n.d. | 90.2 | n.d. | n.d. | 9.0 | n.d. | n.d. |
| *7297* | Raw Copper | 1.1 | 1.2 | 2.6 | n.d. | n.d. | 95.2 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *8002* | Low Tin Bronze | 0.6 | n.d. | n.d. | n.d. | n.d. | 93.5 | n.d. | n.d. | 5.8 | n.d. | n.d. |
| *8020* | Low Tin Bronze | 0.9 | n.d. | n.d. | n.d. | n.d. | 93.2 | 0.5 | n.d. | 5.5 | n.d. | n.d. |
| *8037* | High Tin Bronze | 1.5 | 0.3 | 0.7 | n.d. | n.d. | 90.1 | 0.8 | n.d. | 6.6 | n.d. | n.d. |
| *8040* | Low Tin Bronze | 1.2 | n.d. | n.d. | n.d. | n.d. | 93.9 | 0.4 | n.d. | 4.4 | n.d. | n.d. |
| *8048* | Refined Copper | 0.6 | 0.2 | 0.7 | n.d. | n.d. | 97.0 | 0.8 | n.d. | 0.8 | n.d. | n.d. |
| *8061* | Raw Copper | 0.9 | 0.6 | 3.3 | n.d. | n.d. | 95.2 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *8226* | Raw Copper | 0.8 | 0.9 | 5.3 | n.d. | n.d. | 93.0 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *8237* | Raw Copper | 0.7 | 1.0 | 5.1 | n.d. | n.d. | 93.3 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *8322* | Refined Copper | 0.5 | 0.5 | n.d. | n.d. | n.d. | 98.5 | 0.5 | n.d. | n.d. | n.d. | n.d. |
| *8346* | Raw Copper | 0.4 | 0.5 | 2.8 | n.d. | n.d. | 95.5 | 0.8 | n.d. | n.d. | n.d. | n.d. |
| *8465* | Refined Copper | 0.7 | 0.6 | n.d. | n.d. | n.d. | 98.6 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *8498* | Low Tin Bronze | 0.8 | 0.3 | 0.4 | n.d. | n.d. | 92.8 | 0.5 | n.d. | 5.3 | n.d. | n.d. |
| *8499* | Low Tin Bronze | 2.5 | 0.4 | 0.3 | n.d. | n.d. | 89.7 | 2.5 | n.d. | 4.7 | n.d. | n.d. |
| *8620* | Raw Copper | 0.9 | 0.7 | 8.1 | n.d. | n.d. | 90.3 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *8666* | Raw Copper | 0.7 | 0.8 | 3.2 | 0.6 | 0.7 | 92.8 | 0.7 | n.d. | 0.7 | n.d. | n.d. |
| *8672* | Raw Copper | 0.7 | 0.8 | 2.6 | n.d. | n.d. | 95.6 | 0.4 | n.d. | n.d. | n.d. | n.d. |
| *8676* | High Tin Bronze | 0.9 | n.d. | n.d. | n.d. | n.d. | 87.5 | 0.4 | n.d. | 10.9 | n.d. | 0.3 |
| *8686* | Raw Copper | 0.8 | 0.8 | 5.3 | n.d. | n.d. | 92.9 | 0.2 | n.d. | n.d. | n.d. | n.d. |

| *AT#* | ***Material*** | ***O*** | ***S*** | ***Fe*** | ***Co*** | ***Ni*** | ***Cu*** | ***As*** | ***Ag*** | ***Sn*** | ***Sb*** | ***Pb*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *8904* | High Tin Bronze | 1.1 | 0.3 | 0.3 | n.d. | n.d. | 89.8 | 0.5 | n.d. | 8.0 | n.d. | n.d. |
| *8906* | Refined Copper | 1.2 | 0.2 | 0.5 | n.d. | n.d. | 97.2 | 0.9 | n.d. | n.d. | n.d. | n.d. |
| *8915* | Cupronickel | 0.7 | 0.2 | 0.4 | n.d. | 13.8 | 83.3 | 1.7 | n.d. | n.d. | n.d. | n.d. |
| *16577* | HSP | 0.8 | 0.6 | 3.2 | n.d. | n.d. | 95.4 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *18494* | Low Tin Bronze | 0.5 | n.d. | n.d. | n.d. | n.d. | 96.0 | n.d. | n.d. | 3.4 | n.d. | n.d. |
| *18608* | Refined Copper | 0.6 | 0.3 | 0.2 | n.d. | n.d. | 98.6 | 0.3 | n.d. | n.d. | n.d. | n.d. |
| *18635* | Refined Copper | 0.6 | 0.4 | n.d. | n.d. | n.d. | 99.0 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *19158* | High Tin Bronze | 0.8 | 0.2 | 0.3 | n.d. | n.d. | 87.8 | 0.5 | n.d. | 10.4 | n.d. | n.d. |
| *19177* | High Tin Bronze | 1.4 | n.d. | 0.2 | n.d. | n.d. | 89.4 | 0.9 | n.d. | 8.2 | n.d. | n.d. |
| *19330* | HSP | 0.7 | 0.8 | 7.4 | n.d. | n.d. | 91.0 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *19597* | Speiss | 1.7 | 2.8 | 63.8 | n.d. | n.d. | 1.0 | 28.7 | n.d. | 0.2 | 1.9 | n.d. |
| *20433* | High Tin Bronze | 0.8 | 0.2 | 0.2 | n.d. | 0.2 | 89.3 | 1.0 | n.d. | 8.3 | n.d. | n.d. |
| *20450* | Low Tin Bronze | 0.8 | n.d. | 0.3 | n.d. | n.d. | 93.6 | 0.4 | n.d. | 5.0 | n.d. | n.d. |
| *20638* | Refined Copper | 0.4 | 0.1 | 0.3 | n.d. | n.d. | 98.9 | 0.3 | n.d. | n.d. | n.d. | n.d. |
| *20717* | Refined Copper | 0.6 | 0.4 | n.d. | n.d. | n.d. | 98.6 | 0.3 | n.d. | n.d. | n.d. | n.d. |
| *20765* | Refined Copper | 0.8 | n.d. | n.d. | n.d. | n.d. | 99.2 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *21204* | Cu-Ag-Ni Alloy - β Phase | n.d. | n.d. | 0.3 | 1.5 | 13.0 | 81.9 | n.d. | 3.4 | n.d. | n.d. | n.d. |
| *21204* | Cu-Ag-Ni Alloy - α Phase | 0.6 | n.d. | n.d. | n.d. | n.d. | 7.4 | n.d. | 91.9 | n.d. | n.d. | n.d. |
| *21332* | High Tin Bronze | 0.8 | n.d. | n.d. | n.d. | n.d. | 86.0 | n.d. | n.d. | 13.2 | n.d. | n.d. |
| *21374* | High Tin Bronze | 0.7 | n.d. | 0.2 | n.d. | n.d. | 90.3 | 0.3 | n.d. | 8.5 | n.d. | n.d. |
| *21393* | Refined Copper | 0.8 | 0.2 | n.d. | n.d. | n.d. | 98.9 | 0.1 | n.d. | n.d. | n.d. | n.d. |
| *21454* | Low Tin Bronze | 0.7 | n.d. | 0.2 | n.d. | n.d. | 95.4 | 0.6 | n.d. | 3.0 | n.d. | n.d. |
| *21510* | Low Tin Bronze | 0.7 | 0.1 | 0.4 | n.d. | 0.4 | 94.0 | 0.7 | n.d. | 3.6 | n.d. | n.d. |
| *21536* | Low Tin Bronze | 0.7 | 0.1 | 0.2 | n.d. | n.d. | 97.8 | 0.4 | n.d. | 0.9 | n.d. | n.d. |
| *21719* | HSP | 0.9 | 0.9 | 2.5 | n.d. | n.d. | 95.4 | 0.3 | n.d. | n.d. | n.d. | n.d. |
| *21743* | High Tin Bronze | n.d. | n.d. | n.d. | n.d. | n.d. | 89.7 | n.d. | n.d. | 10.3 | n.d. | n.d. |
| *21778* | High Tin Bronze | 0.8 | 0.2 | 0.3 | n.d. | n.d. | 89.7 | 0.3 | n.d. | 8.7 | n.d. | n.d. |
| *22853* | Raw Copper | 0.4 | n.d. | 2.2 | n.d. | n.d. | 97.0 | 0.4 | n.d. | n.d. | n.d. | n.d. |
| *23469* | HSP | 0.6 | 0.8 | 4.0 | n.d. | n.d. | 94.6 | n.d. | n.d. | n.d. | n.d. | n.d. |
| *23902* | Refined Copper | 0.6 | 0.2 | 0.5 | n.d. | n.d. | 97.9 | 0.8 | n.d. | n.d. | n.d. | n.d. |
| *23953* | Raw Copper | 0.7 | 0.9 | 1.2 | n.d. | n.d. | 97.0 | 0.2 | n.d. | n.d. | n.d. | n.d. |
| *23960* | Raw Copper | 0.6 | 0.2 | 1.0 | n.d. | n.d. | 97.1 | 1.0 | n.d. | n.d. | n.d. | n.d. |
| *24079* | Refined Copper | 0.5 | 0.1 | 0.6 | n.d. | n.d. | 97.7 | 0.7 | n.d. | 0.4 | n.d. | n.d. |
| *24621* | Refined Copper | 0.9 | n.d. | n.d. | n.d. | n.d. | 98.4 | 0.6 | n.d. | n.d. | n.d. | n.d. |
| *25629* | Refined Copper | 0.9 | 0.9 | n.d. | n.d. | n.d. | 97.5 | 0.7 | n.d. | n.d. | n.d. | n.d. |
| *25637* | Raw Copper | 42.6 | 0.3 | n.d. | n.d. | n.d. | 47.9 | 0.3 | n.d. | n.d. | n.d. | n.d. |
| *25650* | High Tin Bronze | 0.9 | n.d. | n.d. | n.d. | n.d. | 89.9 | 0.9 | n.d. | 8.3 | n.d. | n.d. |

Slag analyses:

| AT# | Slag Type | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $SO_3$ | $K_2O$ | CaO | $TiO_2$ | FeO | CoO | NiO | CuO | $As_2O_3$ | $SnO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *4048_2* | Crucible | 1.1 | 1.1 | 4.8 | 15.3 | n.d. | n.d. | 0.7 | 3.6 | n.d. | 39.1 | n.d. | n.d. | 22.7 | n.d. | 11.4 |
| *4100* | Crucible | 0.5 | n.d. | 6.1 | 23.3 | 0.2 | n.d. | 0.8 | 8.7 | 0.2 | 36.9 | n.d. | n.d. | 22.1 | n.d. | 1.1 |
| *4109_1* | Crucible | 0.5 | 2.2 | 4.9 | 27.5 | 0.5 | 0.7 | 0.5 | 4.9 | 0.1 | 53.8 | n.d. | n.d. | 4.4 | n.d. | n.d. |
| *4109_3* | Crucible | 0.5 | 2.6 | 5.6 | 22.1 | 0.2 | 2.1 | 0.3 | 3.6 | 0.1 | 60.8 | n.d. | n.d. | 2.1 | n.d. | n.d. |
| *4327* | Smelting | n.d. | 3.9 | 7.4 | 20.6 | n.d. | 2.5 | 0.1 | 1.4 | 0.1 | 57.5 | n.d. | n.d. | 6.5 | n.d. | n.d. |
| *7762* | Crucible | 0.9 | 3.0 | 6.5 | 33.3 | n.d. | n.d. | 0.7 | 11.3 | 0.4 | 39.2 | 1.7 | 0.1 | 3.0 | n.d. | n.d. |
| *8019* | Smelting | 0.9 | 2.5 | 5.9 | 26.6 | 0.1 | n.d. | 0.3 | 6.3 | n.d. | 46.2 | n.d. | n.d. | 11.2 | n.d. | n.d. |
| *8232* | Crucible | n.d. | 1.5 | 6.1 | 21.3 | n.d. | 0.1 | 0.5 | 2.6 | 0.3 | 63.7 | 0.6 | n.d. | 3.3 | n.d. | n.d. |
| *8236* | Crucible | n.d. | 3.7 | 7.5 | 34.1 | 0.5 | n.d. | 0.8 | 12.8 | 0.4 | 23.2 | n.d. | n.d. | 11.4 | n.d. | 5.6 |
| *8491* | Crucible | 0.5 | 3.9 | 7.8 | 34.6 | 0.2 | n.d. | 1.7 | 23.1 | 0.5 | 8.7 | n.d. | n.d. | 8.9 | n.d. | 10.1 |
| *8680* | Crucible | 0.2 | 1.9 | 7.7 | 33.1 | 0.1 | 0.3 | 0.6 | 10.2 | 0.2 | 31.6 | 0.1 | n.d. | 13.9 | n.d. | n.d. |
| *8699* | Crucible | 0.3 | 3.5 | 7.8 | 32.4 | n.d. | n.d. | 0.6 | 11.0 | 0.3 | 30.7 | 0.2 | n.d. | 7.4 | n.d. | 6.0 |
| *16577* | Smelting | 0.6 | 1.3 | 6.9 | 25.0 | n.d. | 1.9 | 0.3 | 1.9 | 0.1 | 59.0 | n.d. | n.d. | 3.1 | n.d. | n.d. |
| *18636* | Smelting | 0.1 | 2.8 | 9.2 | 28.3 | 0.6 | 1.7 | 0.3 | 4.4 | 0.4 | 46.6 | n.d. | n.d. | 5.6 | n.d. | n.d. |
| *18814* | Crucible | 0.1 | 0.1 | 4.6 | 24.4 | 0.4 | 0.1 | 0.6 | 10.0 | 0.2 | 34.9 | 0.7 | n.d. | 18.1 | 0.6 | 5.4 |
| *19157* | Crucible | n.d. | 0.6 | 4.0 | 18.7 | 0.4 | n.d. | 0.5 | 6.6 | n.d. | 54.0 | 0.3 | n.d. | 10.1 | 0.3 | 4.6 |
| *19330* | Smelting | n.d. | 1.0 | 5.2 | 22.7 | n.d. | 5.2 | 0.8 | 5.5 | n.d. | 57.3 | n.d. | n.d. | 2.4 | n.d. | n.d. |
| *21470* | Smelting | n.d. | 2.6 | 7.3 | 25.9 | 0.2 | 1.2 | 0.4 | 3.8 | 0.2 | 56.1 | n.d. | n.d. | 2.3 | n.d. | n.d. |
| *21719* | Smelting | n.d. | n.d. | 6.1 | 60.0 | n.d. | 1.7 | 0.1 | 0.3 | 0.4 | 24.8 | n.d. | n.d. | 6.6 | n.d. | n.d. |
| *22869* | Crucible | n.d. | 1.7 | 6.0 | 28.0 | 0.4 | 0.2 | 0.9 | 11.1 | 0.3 | 25.3 | 0.2 | n.d. | 15.9 | n.d. | 10.2 |

# Appendix 4: LA-ICP-MS Data

The LA-ICP-MS data are presented here in two parts. The first set of tables presents a comparison of results for the analysis of 17 samples at both the Field Museum (FM) and University of Illinois Urbana-Champaign Geology Department (UIUC). Three additional samples were analyzed (21204, 19597, and 18814). Without appropriately matrix-matched standards for AT21204 and AT19597, the analysis of these samples was exploratory with non-quantitative results. AT18814 was a slag that required repolishing before analysis at UIUC, which unfortunately destroyed the prill that had initially been analyzed, making comparison moot. As mentioned in section 8.1, both sets of analyses were carried out on a Thermo Scientific iCAP quadrupole ICP-MS, but with different laser systems being used for ablation. For the FM analyses neither SRM MBH 32XSN3G nor MBH 36XSP1A were used in quantification or quality assurance in keeping with in-house procedures. For the UIUC series, 32XSN3G was included as an additional quantification standard while 36XSP1A was used for quality assurance (Table 7-8). Mg, Al, and P have been excluded from this comparison since the values were already considered questionable, with %Δ ranging between 50-200%. The second part of this appendix presents the compositional values for all samples analyzed by LA-ICP-MS.

Results are all presented in weight percent.

* - indicates that the sample had substantial intergranular corrosion that was included in the analysis. As such, the result is not a reliable indicator of the true composition of the object.

| *AT#* | *Lab* | $^{52}$*Cr* | $^{55}$*Mn* | $^{57}$*Fe* | $^{59}$*Co* | $^{60}$*Ni* | $^{63}$*Cu* | $^{66}$*Zn* | $^{75}$*As* | $^{82}$*Se* | $^{107}$*Ag* | $^{114}$*Cd* | $^{118}$*Sn* | $^{121}$*Sb* | $^{125}$*Te* | $^{208}$*Pb* | $^{209}$*Bi* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *16577* | FM | 0.000 | 0.000 | 3.645 | 0.033 | 0.013 | 96 | 0.035 | 0.090 | 0.015 | 0.005 | 0.000 | 0.005 | 0.004 | 0.012 | 0.011 | 0.001 |
| | UIUC | 0.000 | 0.000 | 4.096 | 0.031 | 0.014 | 96 | 0.019 | 0.166 | 0.004 | 0.003 | 0.000 | 0.004 | 0.005 | 0.012 | 0.014 | 0.000 |
| | %Δ | 141 | 15 | 12 | 7 | 6 | 0 | 57 | 59 | 120 | 40 | 92 | 25 | 16 | 4 | 29 | 73 |
| *19330* | FM | 0.000 | 0.000 | 3.848 | 0.059 | 0.014 | 96 | 0.037 | 0.254 | 0.018 | 0.005 | 0.000 | 0.008 | 0.006 | 0.033 | 0.011 | 0.001 |
| | UIUC | 0.000 | 0.000 | 3.133 | 0.054 | 0.016 | 96 | 0.023 | 0.420 | 0.003 | 0.004 | 0.000 | 0.003 | 0.007 | 0.007 | 0.011 | 0.000 |
| | %Δ | 127 | 122 | 20 | 9 | 15 | 1 | 45 | 49 | 135 | 21 | 18 | 94 | 1 | 128 | 2 | 96 |
| *20433* | FM | 0.000 | 0.000 | 0.194 | 0.025 | 0.192 | 90 | 0.019 | 0.708 | 0.008 | 0.022 | 0.129 | 8.251 | 0.107 | 0.008 | 0.204 | 0.002 |
| | UIUC | 0.000 | 0.000 | 0.286 | 0.022 | 0.219 | 90 | 0.000 | 0.736 | 0.002 | 0.014 | 0.000 | 8.234 | 0.086 | 0.004 | 0.106 | 0.001 |
| | %Δ | 95 | 38 | 39 | 13 | 13 | 0 | 194 | 4 | 115 | 44 | 200 | 0 | 21 | 63 | 63 | 121 |
| *20717* | FM | 0.000 | 0.000 | 0.007 | 0.007 | 0.008 | 100 | 0.000 | 0.205 | 0.023 | 0.002 | 0.000 | 0.031 | 0.005 | 0.013 | 0.009 | 0.002 |
| | UIUC | 0.000 | 0.000 | 0.003 | 0.007 | 0.007 | 99 | 0.000 | 0.559 | 0.007 | 0.004 | 0.000 | 0.007 | 0.009 | 0.018 | 0.025 | 0.002 |
| | %Δ | 120 | 171 | 74 | 2 | 15 | 0 | 49 | 93 | 111 | 42 | 53 | 128 | 54 | 37 | 94 | 12 |
| *20765* | FM | 0.000 | 0.000 | 0.003 | 0.034 | 0.028 | 100 | 0.003 | 0.015 | 0.015 | 0.002 | 0.000 | 0.004 | 0.004 | 0.003 | 0.033 | 0.000 |
| | UIUC | 0.000 | 0.001 | 0.032 | 0.121 | 0.024 | 100 | 0.004 | 0.029 | 0.008 | 0.003 | 0.000 | 0.004 | 0.014 | 0.002 | 0.002 | 0.000 |
| | %Δ | 176 | 130 | 166 | 111 | 12 | 0 | 35 | 67 | 60 | 26 | 101 | 18 | 108 | 11 | 173 | 8 |
| **21332* | FM | 0.000 | 0.000 | 0.091 | 0.002 | 0.011 | 82 | 0.001 | 0.064 | 0.011 | 0.002 | 0.173 | 17.280 | 0.003 | 0.006 | 0.009 | 0.001 |
| | UIUC | 0.000 | 0.000 | 0.168 | 0.004 | 0.014 | 55 | 0.000 | 0.136 | 0.003 | 0.002 | 0.283 | 44.535 | 0.006 | 0.007 | 0.031 | 0.001 |
| | %Δ | 24 | 110 | 60 | 39 | 26 | 40 | 56 | 72 | 114 | 16 | 48 | 88 | 54 | 9 | 108 | 16 |
| **21374* | FM | 0.000 | 0.000 | 0.308 | 0.046 | 0.054 | 86 | 0.002 | 0.328 | 0.009 | 0.004 | 0.128 | 12.636 | 0.032 | 0.006 | 0.035 | 0.000 |
| | UIUC | 0.000 | 0.000 | 0.263 | 0.029 | 0.028 | 82 | 0.001 | 0.417 | 0.001 | 0.005 | 0.000 | 16.926 | 0.033 | 0.003 | 0.051 | 0.000 |
| | %Δ | 149 | 5 | 16 | 44 | 64 | 5 | 104 | 24 | 170 | 23 | 200 | 29 | 2 | 52 | 37 | 78 |
| *21393* | FM | 0.000 | 0.002 | 0.017 | 0.010 | 0.011 | 100 | 0.001 | 0.196 | 0.018 | 0.001 | 0.000 | 0.011 | 0.005 | 0.014 | 0.014 | 0.001 |
| | UIUC | 0.000 | 0.001 | 0.009 | 0.013 | 0.007 | 100 | 0.000 | 0.315 | 0.007 | 0.001 | 0.000 | 0.003 | 0.005 | 0.012 | 0.008 | 0.001 |
| | %Δ | 54 | 93 | 62 | 22 | 41 | 0 | 47 | 47 | 83 | 7 | 109 | 106 | 3 | 18 | 58 | 52 |
| *21454* | FM | 0.000 | 0.000 | 0.198 | 0.003 | 0.039 | 94 | 0.001 | 0.692 | 0.017 | 0.007 | 0.049 | 4.460 | 0.059 | 0.008 | 0.045 | 0.001 |
| | UIUC | 0.000 | 0.000 | 0.206 | 0.003 | 0.044 | 94 | 0.001 | 0.898 | 0.004 | 0.007 | 0.000 | 4.833 | 0.070 | 0.004 | 0.083 | 0.000 |
| | %Δ | 189 | 123 | 4 | 3 | 11 | 1 | 47 | 26 | 131 | 5 | 200 | 8 | 17 | 81 | 60 | 66 |
| *21719* | FM | 0.000 | 0.000 | 2.747 | 0.085 | 0.014 | 97 | 0.028 | 0.192 | 0.015 | 0.004 | 0.000 | 0.002 | 0.005 | 0.026 | 0.007 | 0.000 |
| | UIUC | 0.000 | 0.000 | 1.798 | 0.051 | 0.012 | 98 | 0.019 | 0.448 | 0.006 | 0.005 | 0.000 | 0.002 | 0.006 | 0.027 | 0.013 | 0.000 |
| | %Δ | 20 | 141 | 42 | 49 | 17 | 1 | 40 | 80 | 87 | 21 | 45 | 17 | 16 | 4 | 66 | 47 |
| *23469* | FM | 0.000 | 0.000 | 3.449 | 0.054 | 0.018 | 96 | 0.027 | 0.243 | 0.009 | 0.008 | 0.000 | 0.004 | 0.010 | 0.014 | 0.018 | 0.001 |
| | UIUC | 0.000 | 0.000 | 4.367 | 0.045 | 0.017 | 95 | 0.009 | 0.515 | 0.002 | 0.007 | 0.000 | 0.003 | 0.012 | 0.006 | 0.008 | 0.000 |
| | %Δ | 64 | 59 | 23 | 18 | 5 | 1 | 105 | 72 | 141 | 17 | 65 | 10 | 18 | 75 | 78 | 18 |
| *23799* | FM | 0.000 | 0.003 | 14.336 | 0.168 | 0.014 | 85 | 0.038 | 0.353 | 0.008 | 0.004 | 0.000 | 0.003 | 0.009 | 0.009 | 0.008 | 0.001 |
| | UIUC | 0.000 | 0.000 | 50.603 | 0.364 | 0.038 | 48 | 0.010 | 1.363 | 0.001 | 0.002 | 0.000 | 0.005 | 0.006 | 0.002 | 0.003 | 0.000 |
| | %Δ | 23 | 152 | 112 | 74 | 89 | 56 | 119 | 118 | 151 | 79 | 31 | 51 | 33 | 114 | 91 | 86 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *23953* | FM | 0.000 | 0.001 | 1.144 | 0.046 | 0.009 | 98 | 0.018 | 0.446 | 0.014 | 0.009 | 0.000 | 0.006 | 0.020 | 0.020 | 0.023 | 0.003 |
| | UIUC | 0.000 | 0.000 | 2.352 | 0.051 | 0.011 | 97 | 0.008 | 0.198 | 0.003 | 0.004 | 0.000 | 0.002 | 0.006 | 0.007 | 0.006 | 0.000 |
| | %Δ | 26 | 78 | 69 | 11 | 28 | 1 | 79 | 77 | 130 | 74 | 124 | 94 | 104 | 96 | 118 | 150 |
| *8226* | FM | 0.000 | 0.000 | 4.749 | 0.044 | 0.016 | 95 | 0.023 | 0.094 | 0.022 | 0.003 | 0.000 | 0.002 | 0.005 | 0.009 | 0.040 | 0.001 |
| | UIUC | 0.000 | 0.001 | 2.969 | 0.021 | 0.016 | 97 | 0.008 | 0.171 | 0.002 | 0.002 | 0.000 | 0.002 | 0.003 | 0.002 | 0.003 | 0.000 |
| | %Δ | 134 | 156 | 46 | 73 | 0 | 2 | 98 | 58 | 163 | 25 | 74 | 29 | 29 | 114 | 176 | 83 |
| *8498* | FM | 0.000 | 0.000 | 0.461 | 0.042 | 0.029 | 94 | 0.005 | 0.417 | 0.021 | 0.009 | 0.074 | 4.970 | 0.028 | 0.026 | 0.025 | 0.001 |
| | UIUC | 0.000 | 0.001 | 0.450 | 0.051 | 0.028 | 94 | 0.003 | 0.388 | 0.003 | 0.006 | 0.000 | 4.983 | 0.021 | 0.005 | 0.016 | 0.000 |
| | %Δ | 16 | 135 | 3 | 20 | 3 | 0 | 64 | 7 | 146 | 47 | 198 | 0 | 27 | 136 | 43 | 108 |
| *8666* | FM | 0.000 | 0.000 | 3.838 | 0.574 | 0.636 | 94 | 0.011 | 0.507 | 0.018 | 0.004 | 0.009 | 0.607 | 0.017 | 0.011 | 0.013 | 0.000 |
| | UIUC | 0.000 | 0.000 | 2.625 | 0.500 | 0.656 | 95 | 0.002 | 0.592 | 0.003 | 0.003 | 0.000 | 0.858 | 0.013 | 0.004 | 0.005 | 0.000 |
| | %Δ | 24 | 40 | 38 | 14 | 3 | 1 | 130 | 16 | 139 | 33 | 195 | 34 | 24 | 87 | 95 | 102 |
| *8672* | FM | 0.000 | 0.000 | 2.283 | 0.067 | 0.036 | 97 | 0.308 | 0.331 | 0.006 | 0.025 | 0.001 | 0.050 | 0.041 | 0.017 | 0.071 | 0.000 |
| | UIUC | 0.000 | 0.000 | 1.470 | 0.056 | 0.032 | 98 | 0.125 | 0.488 | 0.003 | 0.025 | 0.000 | 0.066 | 0.048 | 0.016 | 0.051 | 0.000 |
| | %Δ | 197 | 68 | 43 | 16 | 12 | 1 | 85 | 39 | 61 | 4 | 151 | 27 | 16 | 7 | 33 | 80 |

| *Summary Statistics* | $^{52}Cr$ | $^{55}Mn$ | $^{57}Fe$ | $^{59}Co$ | $^{60}Ni$ | $^{63}Cu$ | $^{66}Zn$ | $^{75}As$ | $^{82}Se$ | $^{107}Ag$ | $^{114}Cd$ | $^{118}Sn$ | $^{121}Sb$ | $^{125}Te$ | $^{208}Pb$ | $^{209}Bi$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Median %Δ* | 95 | 110 | 42 | 18 | 13 | 1 | 64 | 58 | 130 | 25 | 101 | 29 | 21 | 63 | 66 | 78 |
| *Average %Δ* | 93 | 96 | 49 | 31 | 21 | 7 | 80 | 53 | 121 | 31 | 112 | 45 | 32 | 61 | 78 | 70 |
| *%Δ Std. Dev.* | 65 | 52 | 41 | 31 | 24 | 16 | 42 | 31 | 33 | 22 | 67 | 41 | 32 | 47 | 48 | 41 |

Results and summary statistics for UIUC-FM interlaboratory testing. Note that significant variance on $^{114}Cd$ is due to the FM data not being corrected for $^{114}Cd$-$^{114}Sn$ interference.

| AT# | $^{52}Cr$ | $^{55}Mn$ | $^{57}Fe$ | $^{59}Co$ | $^{60}Ni$ | $^{63}Cu$ | $^{66}Zn$ | $^{75}As$ | $^{82}Se$ | $^{107}Ag$ | $^{114}Cd$ | $^{118}Sn$ | $^{121}Sb$ | $^{125}Te$ | $^{208}Pb$ | $^{209}Bi$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *569* | 0.00033 | 0.0004 | 0.6152 | 0.0129 | 0.0553 | 65.37 | 0.0019 | 1.039 | 0.0068 | 0.007 | 0.0000 | 32.574 | 0.0450 | 0.0077 | 0.2586 | 0.0020 |
| *4007* | 0.00164 | 0.0055 | 0.1015 | 0.0176 | 0.0585 | 86.78 | 0.0035 | 1.118 | 0.0106 | 0.015 | 0.0014 | 11.015 | 0.0850 | 0.0016 | 0.7395 | 0.0056 |
| *4048_1* | 0.00139 | 0.0022 | 1.1528 | 0.0079 | 0.0425 | 91.33 | 0.0070 | 0.648 | 0.0124 | 0.046 | 0.0037 | 4.983 | 0.0647 | 0.0059 | 1.6275 | 0.0052 |
| *4101* | 0.00008 | 0.0014 | 0.0508 | 0.0044 | 0.0531 | 95.33 | 0.0011 | 1.056 | 0.0262 | 0.021 | 0.0000 | 3.278 | 0.0740 | 0.0112 | 0.0562 | 0.0002 |
| *4109_1* | 0.00012 | 0.0017 | 0.1685 | 0.0119 | 0.0345 | 81.91 | 0.0025 | 0.929 | 0.0398 | 0.087 | 0.0000 | 15.803 | 0.0559 | 0.0144 | 0.8650 | 0.0005 |
| *4113* | 0.00003 | 0.0001 | 0.1172 | 0.0241 | 0.1255 | 85.99 | 0.0034 | 0.403 | 0.0010 | 0.007 | 0.0000 | 13.259 | 0.0302 | 0.0003 | 0.0316 | 0.0001 |
| *4147* | 0.00258 | 0.0066 | 0.1204 | 0.0554 | 0.0156 | 99.46 | 0.0056 | 0.046 | 0.0158 | 0.006 | 0.0008 | 0.008 | 0.1179 | 0.0053 | 0.0027 | 0.0009 |
| **4148* | 0.00007 | 0.0002 | 0.2129 | 0.0321 | 0.0314 | 57.07 | 0.0018 | 1.166 | 0.0011 | 0.002 | 0.0000 | 41.320 | 0.0410 | 0.0014 | 0.1164 | 0.0009 |
| *4309* | 0.00013 | 0.0007 | 0.2642 | 0.0074 | 0.0415 | 94.96 | 0.0018 | 0.558 | 0.0051 | 0.004 | 0.0001 | 3.943 | 0.0533 | 0.0057 | 0.1478 | 0.0003 |
| *7288* | 0.00126 | 0.0142 | 0.6070 | 0.0284 | 0.0220 | 90.42 | 0.0051 | 0.242 | 0.1847 | 0.017 | 0.0154 | 7.647 | 0.0589 | 0.0353 | 0.0588 | 0.0003 |
| *7297* | 0.00002 | 0.0003 | 3.0231 | 0.0315 | 0.0208 | 96.70 | 0.0152 | 0.183 | 0.0015 | 0.003 | 0.0001 | 0.003 | 0.0053 | 0.0065 | 0.0069 | 0.0002 |
| **8002* | 0.00025 | 0.0007 | 0.1945 | 0.0080 | 0.0217 | 56.00 | 0.0025 | 0.427 | 0.0027 | 0.017 | 0.0000 | 41.509 | 0.0255 | 0.0025 | 1.7725 | 0.0042 |
| *8020* | 0.00174 | 0.0018 | 0.0527 | 0.0127 | 0.0326 | 95.18 | 0.0115 | 0.246 | 0.0142 | 0.015 | 0.0014 | 4.281 | 0.0152 | 0.0037 | 0.0439 | 0.0023 |
| *8040* | 0.00036 | 0.0051 | 0.0447 | 0.0046 | 0.0113 | 94.60 | 0.0028 | 0.208 | 0.0342 | 0.003 | 0.0098 | 4.965 | 0.0427 | 0.0021 | 0.0212 | 0.0009 |
| *8048* | 0.00416 | 0.0115 | 0.9270 | 0.0207 | 0.0260 | 97.34 | 0.0678 | 0.363 | 0.0422 | 0.017 | 0.0020 | 0.834 | 0.0599 | 0.0087 | 0.1027 | 0.0023 |
| *8061* | 0.00056 | 0.0012 | 3.5617 | 0.0321 | 0.0086 | 95.81 | 0.0205 | 0.492 | 0.0088 | 0.008 | 0.0002 | 0.004 | 0.0118 | 0.0096 | 0.0089 | 0.0004 |
| *8226* | 0.00014 | 0.0005 | 2.9689 | 0.0205 | 0.0161 | 96.79 | 0.0079 | 0.171 | 0.0023 | 0.002 | 0.0001 | 0.002 | 0.0034 | 0.0025 | 0.0025 | 0.0002 |
| *8237* | 0.00003 | 0.0002 | 3.0124 | 0.0643 | 0.0277 | 96.47 | 0.0189 | 0.261 | 0.0024 | 0.004 | 0.0002 | 0.104 | 0.0105 | 0.0093 | 0.0099 | 0.0002 |
| *8322* | 0.00011 | 0.0010 | 0.0312 | 0.0322 | 0.0417 | 99.47 | 0.0525 | 0.226 | 0.0072 | 0.009 | 0.0005 | 0.007 | 0.0277 | 0.0040 | 0.0616 | 0.0116 |
| *8346* | 0.00002 | 0.0000 | 4.0808 | 0.0196 | 0.0100 | 95.66 | 0.0123 | 0.185 | 0.0021 | 0.004 | 0.0001 | 0.007 | 0.0070 | 0.0065 | 0.0038 | 0.0001 |
| *8465* | 0.00005 | 0.0005 | 0.0256 | 0.0378 | 0.1413 | 99.59 | 0.0005 | 0.160 | 0.0050 | 0.002 | 0.0002 | 0.006 | 0.0095 | 0.0041 | 0.0057 | 0.0003 |
| *8498* | 0.00011 | 0.0008 | 0.4497 | 0.0509 | 0.0280 | 94.04 | 0.0026 | 0.388 | 0.0033 | 0.006 | 0.0003 | 4.983 | 0.0212 | 0.0049 | 0.0163 | 0.0002 |
| *8499* | 0.00008 | 0.0008 | 0.2681 | 0.0080 | 0.0490 | 97.21 | 0.0014 | 0.426 | 0.0018 | 0.008 | 0.0002 | 1.817 | 0.0499 | 0.0021 | 0.1488 | 0.0005 |
| *8620* | 0.00113 | 0.0045 | 9.6670 | 0.0334 | 0.0159 | 89.38 | 0.0169 | 0.508 | 0.0364 | 0.010 | 0.0009 | 0.018 | 0.0512 | 0.0263 | 0.0447 | 0.0027 |
| *8666* | 0.00004 | 0.0002 | 2.6252 | 0.5000 | 0.6561 | 94.73 | 0.0024 | 0.592 | 0.0034 | 0.003 | 0.0001 | 0.858 | 0.0134 | 0.0045 | 0.0046 | 0.0001 |
| *8672* | 0.00005 | 0.0003 | 1.4704 | 0.0564 | 0.0319 | 97.61 | 0.1247 | 0.488 | 0.0034 | 0.025 | 0.0001 | 0.066 | 0.0479 | 0.0157 | 0.0510 | 0.0002 |

| AT# | $^{52}Cr$ | $^{55}Mn$ | $^{57}Fe$ | $^{59}Co$ | $^{60}Ni$ | $^{63}Cu$ | $^{66}Zn$ | $^{75}As$ | $^{82}Se$ | $^{107}Ag$ | $^{114}Cd$ | $^{118}Sn$ | $^{121}Sb$ | $^{125}Te$ | $^{208}Pb$ | $^{209}Bi$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *8686* | 0.00051 | 0.0028 | 2.5459 | 0.0412 | 0.0087 | 97.13 | 0.0082 | 0.177 | 0.0029 | 0.002 | 0.0000 | 0.004 | 0.0047 | 0.0069 | 0.0050 | 0.0005 |
| *8904* | 0.00005 | 0.0005 | 0.5654 | 0.0364 | 0.0466 | 91.54 | 0.0033 | 0.305 | 0.0239 | 0.006 | 0.0000 | 7.389 | 0.0157 | 0.0240 | 0.0156 | 0.0002 |
| *8906* | 0.00202 | 0.0041 | 0.3992 | 0.0077 | 0.0196 | 98.68 | 0.0135 | 0.383 | 0.0176 | 0.009 | 0.0006 | 0.025 | 0.0699 | 0.0064 | 0.2861 | 0.0034 |
| *16577* | 0.00006 | 0.0002 | 4.0960 | 0.0309 | 0.0142 | 95.62 | 0.0193 | 0.166 | 0.0037 | 0.003 | 0.0000 | 0.004 | 0.0052 | 0.0115 | 0.0141 | 0.0003 |
| *18494* | 0.00009 | 0.0010 | 0.1471 | 0.0097 | 0.0251 | 97.01 | 0.0006 | 0.116 | 0.0042 | 0.002 | 0.0001 | 2.660 | 0.0053 | 0.0029 | 0.0080 | 0.0008 |
| *18608* | 0.00321 | 0.0251 | 0.2741 | 0.0260 | 0.0340 | 97.28 | 0.0105 | 0.872 | 0.1516 | 0.080 | 0.0091 | 0.076 | 0.6559 | 0.0435 | 0.0324 | 0.0019 |
| *18635* | 0.00109 | 0.0024 | 0.0455 | 0.0012 | 0.0232 | 99.74 | 0.0007 | 0.073 | 0.0101 | 0.004 | 0.0005 | 0.008 | 0.0437 | 0.0021 | 0.0028 | 0.0012 |
| *19158* | 0.00032 | 0.0040 | 0.5712 | 0.0233 | 0.0428 | 88.08 | 0.0084 | 0.491 | 0.0785 | 0.016 | 0.0028 | 9.954 | 0.0503 | 0.0318 | 0.0674 | 0.0010 |
| *19330* | 0.00004 | 0.0003 | 3.1329 | 0.0543 | 0.0161 | 96.31 | 0.0235 | 0.420 | 0.0035 | 0.004 | 0.0000 | 0.003 | 0.0065 | 0.0073 | 0.0115 | 0.0002 |
| *20433* | 0.00006 | 0.0005 | 0.2861 | 0.0223 | 0.2185 | 90.28 | 0.0003 | 0.736 | 0.0021 | 0.014 | 0.0000 | 8.234 | 0.0863 | 0.0044 | 0.1064 | 0.0006 |
| *20450* | 0.00025 | 0.0032 | 0.7343 | 0.0251 | 0.0487 | 94.74 | 0.0020 | 0.339 | 0.0116 | 0.006 | 0.0014 | 4.035 | 0.0183 | 0.0078 | 0.0074 | 0.0010 |
| *20717* | 0.00004 | 0.0004 | 0.0033 | 0.0070 | 0.0069 | 99.34 | 0.0003 | 0.559 | 0.0065 | 0.004 | 0.0001 | 0.007 | 0.0093 | 0.0183 | 0.0246 | 0.0017 |
| *20765* | 0.00030 | 0.0014 | 0.0316 | 0.1209 | 0.0244 | 99.71 | 0.0038 | 0.029 | 0.0082 | 0.003 | 0.0001 | 0.004 | 0.0136 | 0.0024 | 0.0024 | 0.0002 |
| *21204 - α* | 0.00001 | 0.0001 | 0.0315 | 0.1125 | 1.2361 | 40.49 | 0.0003 | 0.062 | 0.0009 | 57.913 | 0.0001 | 0.069 | 0.0108 | 0.0014 | 0.0585 | 0.0088 |
| *21204 - β* | 0.00000 | 0.0001 | 0.6399 | 2.3683 | 16.2400 | 80.59 | 0.0004 | 0.123 | 0.0006 | 0.002 | 0.0000 | 0.023 | 0.0040 | 0.0010 | 0.0023 | 0.0000 |
| **21374* | 0.00000 | 0.0001 | 0.2628 | 0.0293 | 0.0276 | 82.24 | 0.0005 | 0.417 | 0.0007 | 0.005 | 0.0000 | 16.926 | 0.0329 | 0.0034 | 0.0512 | 0.0002 |
| *21393* | 0.00004 | 0.0007 | 0.0091 | 0.0128 | 0.0072 | 99.59 | 0.0005 | 0.315 | 0.0072 | 0.001 | 0.0001 | 0.003 | 0.0054 | 0.0119 | 0.0080 | 0.0006 |
| *21454* | 0.00010 | 0.0003 | 0.2062 | 0.0027 | 0.0437 | 93.83 | 0.0006 | 0.898 | 0.0035 | 0.007 | 0.0000 | 4.833 | 0.0702 | 0.0035 | 0.0833 | 0.0003 |
| *21510* | 0.00004 | 0.0009 | 0.6498 | 0.0152 | 0.5162 | 95.72 | 0.0010 | 0.384 | 0.0036 | 0.009 | 0.0000 | 2.348 | 0.0484 | 0.0068 | 0.2902 | 0.0015 |
| *21536* | 0.00056 | 0.0045 | 0.4210 | 0.0127 | 0.0174 | 98.49 | 0.0028 | 0.259 | 0.0139 | 0.007 | 0.0004 | 0.671 | 0.0315 | 0.0052 | 0.0234 | 0.0009 |
| *21719* | 0.00002 | 0.0005 | 1.7984 | 0.0513 | 0.0118 | 97.58 | 0.0186 | 0.448 | 0.0061 | 0.005 | 0.0001 | 0.002 | 0.0062 | 0.0267 | 0.0130 | 0.0003 |
| **21743* | 0.00015 | 0.0005 | 0.0893 | 0.0185 | 0.0230 | 77.44 | 0.0016 | 0.493 | 0.0033 | 0.002 | 0.0000 | 21.898 | 0.0088 | 0.0027 | 0.0064 | 0.0004 |
| *21778* | 0.00013 | 0.0003 | 0.2897 | 0.0251 | 0.0342 | 90.54 | 0.0029 | 0.514 | 0.0015 | 0.007 | 0.0000 | 8.517 | 0.0251 | 0.0020 | 0.0323 | 0.0005 |
| *22853* | 0.00008 | 0.0008 | 3.6977 | 0.0443 | 0.0198 | 96.05 | 0.0185 | 0.145 | 0.0021 | 0.004 | 0.0000 | 0.002 | 0.0055 | 0.0058 | 0.0056 | 0.0002 |
| *23469* | 0.00008 | 0.0003 | 4.3669 | 0.0452 | 0.0170 | 95.01 | 0.0086 | 0.515 | 0.0016 | 0.007 | 0.0000 | 0.003 | 0.0118 | 0.0062 | 0.0077 | 0.0004 |
| *23799* | 0.00012 | 0.0003 | 50.6025 | 0.3637 | 0.0379 | 47.59 | 0.0097 | 1.363 | 0.0011 | 0.002 | 0.0001 | 0.005 | 0.0063 | 0.0024 | 0.0029 | 0.0002 |
| *23902* | 0.00039 | 0.0094 | 0.5170 | 0.0234 | 0.1990 | 98.36 | 0.0110 | 0.407 | 0.0392 | 0.081 | 0.0013 | 0.076 | 0.0659 | 0.0091 | 0.1057 | 0.0012 |
| *23953* | 0.00004 | 0.0003 | 2.3522 | 0.0515 | 0.0114 | 97.34 | 0.0079 | 0.198 | 0.0029 | 0.004 | 0.0000 | 0.002 | 0.0064 | 0.0070 | 0.0060 | 0.0004 |
| *23960* | 0.02618 | 0.0066 | 1.1281 | 0.0223 | 0.1037 | 97.44 | 0.0051 | 1.008 | 0.0053 | 0.011 | 0.0002 | 0.029 | 0.0219 | 0.0039 | 0.0377 | 0.0030 |
| *24079* | 0.00124 | 0.0031 | 0.6125 | 0.0168 | 0.0271 | 98.37 | 0.0081 | 0.416 | 0.0155 | 0.010 | 0.0020 | 0.394 | 0.0440 | 0.0043 | 0.0288 | 0.0004 |

| *AT#* | $^{52}Cr$ | $^{55}Mn$ | $^{57}Fe$ | $^{59}Co$ | $^{60}Ni$ | $^{63}Cu$ | $^{66}Zn$ | $^{75}As$ | $^{82}Se$ | $^{107}Ag$ | $^{114}Cd$ | $^{118}Sn$ | $^{121}Sb$ | $^{125}Te$ | $^{208}Pb$ | $^{209}Bi$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *24621* | 0.00036 | 0.0041 | 0.6354 | 0.0056 | 0.0649 | 97.88 | 0.0021 | 0.601 | 0.0828 | 0.051 | 0.0005 | 0.131 | 0.1299 | 0.0169 | 0.1805 | 0.0150 |
| *25629* | 0.00036 | 0.0031 | 0.0468 | 0.0458 | 0.0177 | 99.16 | 0.0084 | 0.530 | 0.0168 | 0.007 | 0.0001 | 0.025 | 0.0285 | 0.0182 | 0.0306 | 0.0015 |
| *25650* | 0.00012 | 0.0021 | 0.0728 | 0.0061 | 0.0824 | 90.78 | 0.0013 | 0.588 | 0.0099 | 0.021 | 0.0001 | 8.322 | 0.0467 | 0.0088 | 0.0471 | 0.0006 |

LA-ICP-MS composition data.

# Appendix 5: Lead Isotope Data

The following lead isotope data consist of archaeological samples collected specifically for this study as well as several ore samples originally collected by Prof. K. Aslıhan Yener during her work in the Taurus and Amanus mountains. Geological ore samples are marked with a distinguished with a KG number. Analyses were conducted at the University of Illinois Urbana-Champaign Geology Department using MC-ICP-MS under the supervision and guidance of Prof. Craig Lundstrom. A detailed methodology is laid out in section 8.1. As can be seen in the results for analyses of SRM981 run alongside the Alalakh dataset, there is a consistent offset relative to SRM981 values reported in Todt et al. (2013). All results have been corrected for this offset, meaning that they are reliably comparable with other datasets. Finally, $^{202}Hg$ was monitored across all analyses and found negligible enough to exclude possible interference from $^{204}Hg$.

| *Yener DTB#* | *Sample #* | *Origin* | *Material* | *Object* | $^{208/206}Pb$ | $^{207/206}Pb$ | $^{204/206}Pb$ | $^{208/204}Pb$ | $^{207/204}Pb$ | $^{206/204}Pb$ |
|---|---|---|---|---|---|---|---|---|---|---|
| *AAUI28* | 4007 | Area 4 | Cu-based | Flow | 2.0583 | 0.8282 | 0.0527 | 39.1010 | 15.7201 | 18.9675 |
| *AAUI116* | 4048_1 | Area 4 | Cu-based | Prill | 2.0557 | 0.8271 | 0.0527 | 39.0793 | 15.7115 | 18.9813 |
| *AAUI117* | 4048_2 | Area 4 | Slag | Crucible Slag | 2.0574 | 0.8276 | 0.0527 | 39.0953 | 15.7127 | 18.9725 |
| *AAUI118* | 4048_3 | Area 4 | Speiss | Amorphous | 2.0552 | 0.8261 | 0.0526 | 39.1364 | 15.7192 | 19.0134 |
| *AAUI29* | 4100 | Area 4 | Slag | Crucible Slag | 2.0586 | 0.8310 | 0.0531 | 38.8346 | 15.6631 | 18.8354 |
| *AAUI30* | 4101 | Area 4 | Cu-based | Amorphous | 2.0589 | 0.8294 | 0.0528 | 39.0605 | 15.7231 | 18.9422 |
| *AAUI119* | 4109_2 | Area 4 | Cu-based | Prill | 2.0675 | 0.8352 | 0.0532 | 38.8949 | 15.6998 | 18.7843 |
| *AAUI120* | 4109_2 | Area 4 | Soil | Workshop Floor | 2.0527 | 0.8258 | 0.0527 | 39.0027 | 15.6796 | 18.9723 |
| *AAUI121* | 4109_3 | Area 4 | Slag | Crucible Slag | 2.0581 | 0.8308 | 0.0531 | 38.8437 | 15.6685 | 18.8446 |
| *AAUI31* | 4113 | Area 4 | Cu-based | Rim | 2.0626 | 0.8364 | 0.0533 | 38.7352 | 15.6949 | 18.7525 |
| *AAUI32* | 4139 | Area 4 | Cu-based | Shaft | 2.0632 | 0.8282 | 0.0527 | 39.1920 | 15.7196 | 18.9665 |
| *AAUI33* | 4147 | Area 4 | Cu-based | Amorphous | 2.0655 | 0.8383 | 0.0538 | 38.4566 | 15.5947 | 18.5902 |
| *AAUI34* | 4148 | Area 4 | Cu-based | Sheet | 2.0542 | 0.8265 | 0.0526 | 39.0765 | 15.7100 | 18.9934 |
| *AAUI35* | 4309 | Area 4 | Cu-based | Amorphous | 2.0604 | 0.8290 | 0.0528 | 39.0920 | 15.7160 | 18.9444 |
| *AAUI36* | 4318 | Area 4 | Cu-based | Shaft | 2.0584 | 0.8291 | 0.0528 | 39.0236 | 15.7070 | 18.9294 |
| *AAUI37* | 4327 | Area 4 | Slag | Smelting Slag | 2.0682 | 0.8382 | 0.0538 | 38.5093 | 15.5950 | 18.5906 |
| *AAUI38* | 6393 | Area 1 | Speiss | Amorphous | 2.0540 | 0.8261 | 0.0526 | 39.0831 | 15.7078 | 18.9992 |
| *AAUI39* | 7288 | Area 4 | Cu-based | Pin/Needle | 2.0579 | 0.8285 | 0.0528 | 39.0116 | 15.6944 | 18.9284 |
| *AAUI40* | 7297 | Area 4 | Cu-based | Amorphous | 2.0700 | 0.8392 | 0.0537 | 38.6300 | 15.6492 | 18.6336 |
| *AAUI41* | 7762 | Area 4 | Slag | Crucible Slag | 2.0578 | 0.8287 | 0.0528 | 39.0221 | 15.7032 | 18.9331 |
| *AAUI42* | 8002 | Area 4 | Cu-based | Sheet | 2.0572 | 0.8274 | 0.0528 | 38.9978 | 15.6725 | 18.9273 |
| *AAUI44* | 8019 | Area 4 | Slag | Smelting Slag | 2.0672 | 0.8304 | 0.0530 | 39.0945 | 15.6924 | 18.8832 |
| *AAUI45* | 8020 | Area 4 | Cu-based | Amorphous | 2.0611 | 0.8301 | 0.0529 | 39.0360 | 15.7113 | 18.9125 |
| *AOUI46* | 8039 | Area 4 | Ore | Cu-Pb | 2.0884 | 0.8487 | 0.0540 | 38.7227 | 15.7248 | 18.5124 |
| *AAUI47* | 8040 | Area 4 | Cu-based | Amorphous | 2.0571 | 0.8282 | 0.0529 | 38.9345 | 15.6635 | 18.8980 |
| *AAUI48* | 8048 | Area 4 | Cu-based | Sheet | 2.0588 | 0.8296 | 0.0528 | 39.0193 | 15.7103 | 18.9237 |
| *AAUI49* | 8061 | Area 4 | Cu-based | Amorphous | 2.0728 | 0.8407 | 0.0540 | 38.4610 | 15.5886 | 18.5269 |
| *AAUI50* | 8089 | Area 4 | Cu-based | Amorphous | 2.0577 | 0.8293 | 0.0530 | 38.8864 | 15.6597 | 18.8693 |
| *AAUI51* | 8226 | Area 4 | Cu-based | Amorphous | 2.0696 | 0.8383 | 0.0537 | 38.5631 | 15.6060 | 18.6052 |
| *AAUI52* | 8232 | Area 4 | Slag | Crucible Slag | 2.0666 | 0.8385 | 0.0538 | 38.4821 | 15.6013 | 18.5912 |
| *AAUI53* | 8236 | Area 4 | Slag | Crucible Slag | 2.0589 | 0.8315 | 0.0530 | 38.9009 | 15.6982 | 18.8654 |
| *AAUI54* | 8237 | Area 4 | Cu-based | Point | 2.0733 | 0.8405 | 0.0539 | 38.5025 | 15.5965 | 18.5417 |
| *AAUI55* | 8322 | Area 4 | Cu-based | Amorphous | 2.0584 | 0.8283 | 0.0531 | 38.8554 | 15.6237 | 18.8486 |
| *AAUI56* | 8465 | Area 4 | Cu-based | Amorphous | 2.0722 | 0.8402 | 0.0539 | 38.5317 | 15.6105 | 18.5666 |
| *AAUI58* | 8491 | Area 4 | Cu-based | Crucible Slag | 2.0593 | 0.8294 | 0.0529 | 38.9836 | 15.6893 | 18.9027 |
| *AAUI59* | 8495 | Area 4 | Cu-based | Sheet | 2.0684 | 0.8349 | 0.0532 | 38.9284 | 15.7005 | 18.7911 |
| *AAUI60* | 8499 | Area 4 | Cu-based | Point | 2.0557 | 0.8268 | 0.0526 | 39.1072 | 15.7168 | 18.9944 |

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|---|---|---|---|---|---|---|---|---|---|---|
| *AAUI61* | 8620 | Area 4 | Cu-based | Amorphous | 2.0708 | 0.8403 | 0.0539 | 38.4575 | 15.5924 | 18.5424 |
| *AAUI62* | 8623 | Area 4 | Pb-based | Rod | 2.0554 | 0.8269 | 0.0527 | 39.0689 | 15.7052 | 18.9788 |
| *AAUI63* | 8666 | Area 4 | Cu-based | Blade | 2.0663 | 0.8328 | 0.0531 | 38.9378 | 15.6822 | 18.8159 |
| *AAUI64* | 8672 | Area 4 | Cu-based | Amorphous | 2.0701 | 0.8404 | 0.0539 | 38.4339 | 15.5904 | 18.5380 |
| *AAUI65* | 8676 | Area 4 | Cu-based | Crescent | 2.1325 | 0.8821 | 0.0564 | 37.8700 | 15.6521 | 17.7312 |
| *AAUI66* | 8680 | Area 4 | Slag | Crucible Slag | 2.0575 | 0.8291 | 0.0529 | 38.9701 | 15.6904 | 18.9113 |
| *AAUI67* | 8699 | Area 4 | Slag | Crucible Slag | 2.0555 | 0.8282 | 0.0529 | 38.9166 | 15.6688 | 18.9042 |
| *AAUI68* | 8906 | Area 4 | Cu-based | Wire | 2.0550 | 0.8269 | 0.0527 | 39.0622 | 15.7056 | 18.9797 |
| *AAUI69* | 16577 | Area 1 | Cu-based | HSP | 2.0746 | 0.8411 | 0.0540 | 38.5007 | 15.5983 | 18.5316 |
| *AAUI73* | 18494 | Area 4 | Cu-based | Awl | 2.0609 | 0.8330 | 0.0532 | 38.8047 | 15.6712 | 18.8004 |
| *AAUI74* | 18608 | Area 4 | Cu-based | Sheet | 2.0551 | 0.8272 | 0.0527 | 39.0253 | 15.6959 | 18.9606 |
| *AAUI75* | 18609 | Area 4 | Cu-based | Amorphous | 2.0702 | 0.8400 | 0.0539 | 38.4589 | 15.5926 | 18.5488 |
| *AAUI76* | 18635 | Area 4 | Cu-based | Amorphous | 2.0620 | 0.8358 | 0.0535 | 38.5720 | 15.6228 | 18.6777 |
| *AAUI77* | 18636 | Area 4 | Cu-based | HSP | 2.0720 | 0.8407 | 0.0540 | 38.4572 | 15.5911 | 18.5321 |
| *AAUI78* | 18814 | Area 4 | Slag | Crucible Slag | 2.0598 | 0.8299 | 0.0530 | 38.9427 | 15.6780 | 18.8784 |
| *AAUI81* | 19157 | Area 1 | Slag | Crucible Slag | 2.0640 | 0.8323 | 0.0532 | 38.8799 | 15.6659 | 18.8082 |
| *AAUI82* | 19158 | Area 4 | Cu-based | Shaft | 2.0625 | 0.8312 | 0.0530 | 38.9748 | 15.6944 | 18.8684 |
| *AAUI83* | 19162 | Area 4 | Cu-based | Shaft | 2.0577 | 0.8285 | 0.0528 | 39.0409 | 15.7064 | 18.9438 |
| *AAUI84* | 19172 | Area 4 | Cu-based | Amorphous | 2.0664 | 0.8294 | 0.0528 | 39.1756 | 15.7127 | 18.9307 |
| *AAUI85* | 19177 | Area 4 | Cu-based | Amorphous | 2.0564 | 0.8284 | 0.0528 | 39.0267 | 15.7080 | 18.9487 |
| *AAUI87* | 19447 | Area 1 | Cu-based | Amorphous | 2.0666 | 0.8299 | 0.0529 | 39.1150 | 15.6959 | 18.8984 |
| *AAUI88* | 19597 | Area 1 | Speiss | Parting Layer | 2.0540 | 0.8262 | 0.0526 | 39.1104 | 15.7205 | 19.0121 |
| *AAUI89* | 19901 | Area 1 | Cu-based | Amorphous | 2.0718 | 0.8407 | 0.0540 | 38.4597 | 15.5929 | 18.5350 |
| *AAUI90* | 19926 | Area 1 | Cu-based | Amorphous | 2.0658 | 0.8313 | 0.0529 | 39.0803 | 15.7130 | 18.8887 |
| *AAUI91* | 20433 | Area 1 | Cu-based | Amorphous | 2.0653 | 0.8321 | 0.0530 | 39.0094 | 15.7046 | 18.8586 |
| *AAUI92* | 20638 | Area 1 | Cu-based | Chisel | 2.0572 | 0.8282 | 0.0528 | 39.0294 | 15.7009 | 18.9429 |
| *AAUI93* | 20717 | Area 4 | Cu-based | Amorphous | 2.0667 | 0.8384 | 0.0538 | 38.4740 | 15.5952 | 18.5869 |
| *AAUI94* | 20765 | Area 4 | Cu-based | Amorphous | 2.0609 | 0.8286 | 0.0530 | 38.9776 | 15.6588 | 18.8847 |
| *AAUI95* | 21294 | Area 4 | Ore | Galena | 2.0953 | 0.8505 | 0.0543 | 38.6579 | 15.6790 | 18.4230 |
| *AAUI96* | 21332 | Area 4 | Cu-based | Shaft | 2.0579 | 0.8287 | 0.0528 | 39.0041 | 15.6946 | 18.9247 |
| *AAUI97* | 21374 | Area 4 | Cu-based | Amorphous | 2.0621 | 0.8293 | 0.0528 | 39.1108 | 15.7158 | 18.9368 |
| *AAUI98* | 21393 | Area 4 | Cu-based | Amorphous | 2.0683 | 0.8384 | 0.0538 | 38.5358 | 15.6089 | 18.6035 |
| *AAUI99* | 21454 | Area 1 | Cu-based | Strainer | 2.0608 | 0.8287 | 0.0528 | 39.0588 | 15.6960 | 18.9250 |
| *AAUI100* | 21510 | Area 1 | Cu-based | Awl | 2.0662 | 0.8300 | 0.0529 | 39.1246 | 15.7041 | 18.9072 |
| *AAUI101* | 21536 | Area 1 | Cu-based | Awl | 2.0561 | 0.8282 | 0.0528 | 38.9691 | 15.6839 | 18.9239 |
| *AAUI102* | 21743 | Area 4 | Cu-based | Shaft | 2.0580 | 0.8304 | 0.0530 | 38.8849 | 15.6781 | 18.8653 |
| *AAUI103* | 22853 | Area 4 | Cu-based | Amorphous | 2.0716 | 0.8401 | 0.0539 | 38.4820 | 15.5937 | 18.5469 |
| *AAUI104* | 23469 | Area 4 | Cu-based | HSP | 2.0715 | 0.8409 | 0.0540 | 38.4210 | 15.5838 | 18.5188 |

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|---|---|---|---|---|---|---|---|---|---|---|
| *AAUI105* | 23729 | Area 1 | Cu-based | Sheet | 2.0643 | 0.8343 | 0.0534 | 38.7373 | 15.6438 | 18.7368 |
| *AAUI106* | 23902 | Area 1 | Cu-based | Point | 2.0742 | 0.8335 | 0.0531 | 39.1127 | 15.7056 | 18.8282 |
| *AAUI23* | 23953 | Area 1 | Cu-based | Amorphous | 2.0582 | 0.8312 | 0.0530 | 38.8689 | 15.6849 | 18.8556 |
| *AAUI108* | 23960 | Area 1 | Cu-based | Shaft | 2.0717 | 0.8344 | 0.0533 | 38.9466 | 15.6730 | 18.7702 |
| *AAUI109* | 24621 | Area 1 | Cu-based | Point | 2.0978 | 0.8620 | 0.0554 | 37.9349 | 15.5752 | 18.0561 |
| *AAUI110* | 25628 | Area 4 | Cu-based | Amorphous | 2.0707 | 0.8401 | 0.0538 | 38.5357 | 15.6224 | 18.5804 |
| *AAUI111* | 25629 | Area 4 | Cu-based | Amorphous | 2.0714 | 0.8403 | 0.0540 | 38.4483 | 15.5839 | 18.5320 |
| *AAUI112* | 25637 | Area 4 | Cu-based | Amorphous | 2.0719 | 0.8402 | 0.0539 | 38.4821 | 15.5927 | 18.5448 |
| *AAUI113* | 25644 | Area 4 | Cu-based | Sheet | 2.0653 | 0.8334 | 0.0532 | 38.8871 | 15.6793 | 18.8000 |
| *AAUI114* | 25650 | Area 4 | Cu-based | Amorphous | 2.0618 | 0.8295 | 0.0528 | 39.0718 | 15.7067 | 18.9217 |
| *AAUI115* | 25687 | Area 4 | Cu-based | Sheet | 2.0576 | 0.8290 | 0.0529 | 38.9857 | 15.6949 | 18.9182 |
| *AOUI1* | KG16854 | Kisecik | Ore | Malachite | 2.0915 | 0.8565 | 0.0548 | 38.2116 | 15.6351 | 18.2427 |
| *AOUI2* | KG17132 | Iskenderun | Ore | Malachite | 2.0858 | 0.8535 | 0.0542 | 38.5337 | 15.7580 | 18.4488 |
| *AOUI3* | KG17481 | Kisecik | Ore | Arsenopyrite, Chalcopyrite | 2.0432 | 0.8192 | 0.0523 | 39.1082 | 15.6686 | 19.1118 |
| *AOUI4* | KG18969 | Hassa | Ore | Malachite | 2.0787 | 0.8425 | 0.0537 | 38.8025 | 15.7143 | 18.6383 |
| *AOUI5* | KG18970 | Hassa | Ore | Azurite | 2.0770 | 0.8420 | 0.0536 | 38.7856 | 15.7104 | 18.6458 |
| *AOUI6* | KG19342 | Çamardı | Ore | Malachite | 2.0707 | 0.8359 | 0.0532 | 38.9533 | 15.7126 | 18.7836 |

| *SRM 981 Values* | $^{208/206}Pb$ | $^{207/206}Pb$ | $^{204/206}Pb$ | $^{208/204}Pb$ | $^{207/204}Pb$ | $^{206/204}Pb$ |
|---|---|---|---|---|---|---|
| | 2.1643 | 0.9138 | 0.05908 | 36.6351 | 15.4699 | 16.9273 |
| | 2.1648 | 0.9141 | 0.05908 | 36.6395 | 15.4723 | 16.9254 |
| | 2.1648 | 0.9142 | 0.05908 | 36.6403 | 15.4731 | 16.9260 |
| | 2.1643 | 0.9140 | 0.05908 | 36.6345 | 15.4711 | 16.9265 |
| | 2.1649 | 0.9141 | 0.05906 | 36.6535 | 15.4768 | 16.9312 |
| | 2.1650 | 0.9142 | 0.05905 | 36.6597 | 15.4795 | 16.9334 |
| | 2.1646 | 0.9142 | 0.05910 | 36.6288 | 15.4703 | 16.9215 |
| | 2.1646 | 0.9142 | 0.05908 | 36.6367 | 15.4724 | 16.9251 |
| | 2.1649 | 0.9142 | 0.05907 | 36.6468 | 15.4757 | 16.9280 |
| | 2.1647 | 0.9142 | 0.05910 | 36.6292 | 15.4701 | 16.9214 |
| | 2.1647 | 0.9143 | 0.05910 | 36.6256 | 15.4701 | 16.9196 |
| | 2.1647 | 0.9143 | 0.05910 | 36.6293 | 15.4708 | 16.9203 |
| | 2.1648 | 0.9143 | 0.05910 | 36.6338 | 15.4723 | 16.9219 |
| | 2.1650 | 0.9144 | 0.05909 | 36.6400 | 15.4742 | 16.9236 |
| | 2.1649 | 0.9144 | 0.05910 | 36.6331 | 15.4728 | 16.9215 |
| | 2.1650 | 0.9144 | 0.05909 | 36.6397 | 15.4742 | 16.9231 |
| | 2.1640 | 0.9140 | 0.05908 | 36.6270 | 15.4697 | 16.9252 |
| | 2.1644 | 0.9140 | 0.05906 | 36.6458 | 15.4756 | 16.9315 |
| | 2.1645 | 0.9141 | 0.05907 | 36.6392 | 15.4734 | 16.9278 |

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